REPORT 59

SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION

DU MILIEU PEDOLOGIQUE

ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

MANURE MANAGEMENT IN CONSERVATION FARMING

FINAL REPORT

June, 1992

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On Behalf of: AGRICULTURE CANADA
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Manure Management in Conservation Farming Systems

Final Report
September 1992

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Executive Summary

The agronomic use of manure was evaluated in four major field crops in Southern Ontario (corn, soybeans, winter wheat and alfalfa) over a three year period (1989-91). The principle objective of the research was to identify manure management systems which result in good agronomic yields and minimize the potential for environmental pollution. Systems were developed which emphasized nutrient cycling and ground cover. Cover crops, crop rotation and reduced tillage were considered to be important components in the development of a more holistic manure management system. The experiments were conducted on farms with the active participation of four farmer cooperators.

The overall approach in the research trials was to :

1) apply manure during a low runoff period (late summer), incorporate manure with surface tillage, seed a fast growing cover crop (to conserve nutrients and provide ground cover) and subsequently establish the main crop the following spring using a conservation tillage system;
2) apply manure during a high runoff period (spring, early summer) directly to an established crop (providing high ground cover) and prior to a period of high biomass accumulation (minimizing nutrient leaching potential).

Individual findings from the experiments are summarized below.

Expt. 1. Effect of Oilseed Radish, Timing of Manure Application and Tillage System on Nutrient Cycling and Corn Performance (Within a Winter Wheat-Corn Sequence)

Seeding of an oilseed radish catch crop following a late summer liquid manure application improved nutrient cycling. Oilseed radish took up approximately 100 kg N, 15 kg P and 125 kg K from the soil in the fall. The potential for fall nitrate leaching was reduced by the oilseed radish as soil nitrate levels (at 4 sites) and soil moisture levels (at 1 site) were lowered. In 1990, oilseed radish caused a temporary immobilization of P at the silt loam site which was observed as lower tissue P levels in whole corn plants harvested at the 5 leaf stage. Potassium uptake was lowest in plots where corn was no-tilled into oilseed radish residue and highest where oilseed radish had been plowed in the previous fall. Use of oilseed radish generally increased fall soil cover but lowered soil cover in the spring. Minimum tillage systems (Aerway and zero-till) were the most effective systems for maintaining residue cover and reducing runoff and soil loss. Tillage reduction improved P nutrition at the 5 leaf stage but reduced N and K ear leaf tissue content in corn at silking. Corn yields under minimum tillage were generally equivalent to conventional tillage when sufficient levels of N were available. Spring liquid manure applications resulted in higher N availability in corn than manure applied during the late summer of the previous year. Using split applications of liquid manure (30,000-40,000 l/ha), the first in late summer (followed by seeding of oilseed radish) and the second the following spring is suggested as an alternative to one high rate application (75,000 l/ha) either in late summer or early spring.

Expt. 2. Effect of Manure and Rye Cover Crop on No-Till Soybean Production

Rye seeded late in the summer appeared to be a promising cover crop to reduce erosion and P surface loss potential following a late summer incorporation of manure. Seeding of winter rye (Aug. 30 or Sept. 1) after solid manure application provided high ground cover ratings in the fall (90-91%) and again the following spring after no-till soybean planting (96-100%). At the time of soybean planting, the winter rye provided a high biomass yielding surface mulch (> 5 t/ha) with a low P content (.28-.31%) which would further reduce potential for P surface loss. However, the winter rye appeared to be affecting soybean development and yield. This was examined more fully in the second year of the study. Late summer seeded rye cover crops took up approximately 40-50 kg N/ha in the spring which depleted soil nitrogen at the time of no-till soybean planting. Early season soybean dry matter accumulation, leaf tissue content (N and P) and yield appeared to be most affected by treatments which had the highest rye biomass at the time of soybean planting. The use of solid manure applied prior to rye seeding did not appear to relieve nutrient deficiency problems in the no-till soybeans. The solid manure in the present study contained large quantities of straw which may have retained manure nutrients. Use of liquid manure in conjunction with winter rye would probably have been a more effective system for no-till soybean production as a relatively high N: low C manure source would be used in conjunction with a low N: high C cover crop.

Expt. 3. Effect of Tillage System, Manure Form and Rate on Winter Wheat

The combination of no-till or aerial seeding winter wheat in conjunction with low rate spring liquid manure applications appeared to be a promising low external input wheat production system that minimized surface runoff potential. Aerial, no-till and conventional seeding of winter wheat following soybeans resulted in equivalent wheat yields in both years when averaged over fertility treatments (compost, liquid manure, N fertilizer). All three tillage systems resulted in high ground cover ratings (>50%) at the time fertility treatments were applied in late April. Ratings were highest on winter wheat established using a conservation tillage system. In both years, liquid swine manure applied at 40,000 l/ha to the winter wheat provided equivalent yields to nitrogen fertilizer. Mature compost applied on the surface at rates up to 15 t/ha did not increase yields compared to the control in 1989. Immature compost applied at rates of 40 t/ha increased wheat flag leaf N and P and wheat yield in 1990, but yields were lower than with liquid manure or fertilizer. In both years red clover was undersown in the winter wheat as a fall cover crop to further protect the soil after winter wheat harvest. Red clover biomass production was reduced and fall weed biomass increased in treatments where soluble N forms (liquid manure and fertilizer N) were used to fertilize the winter wheat. The main differences among the two conservation planting techniques was that aerial seeding resulted in greater ground cover (1990) and a higher flag leaf N content (1991) than no-till seeding. This was attributed to the earlier establishment of winter wheat in the aerial seeded plots.

Expt. 4. Effect of Solid Manure, Compost and Fertilizer on Established Forages

Overall, the risk of runoff and soil erosion from a perennial forage stand to which low rates of solid manure or compost had been applied appeared low. The annual application of low rates of solid manure (10 t/ha) or compost (7.5 t/ha) and fertilizer (0-30-135) moderately stimulated forage yields on an established alfalfa-timothy hay stand. All three fertilizer sources increased total forage yield but yields were highest when solid manure was applied. All three fertilizer sources increased alfalfa yield compared to the unfertilized control plot. As well, the solid manure treatment increased the grass yield of the forage stand which was responsible for the increase in total forage yield in this treatment. Throughout the course of the study, soil nutrient levels declined so that levels were very low at the end of the experiment. The fertility treatments did not maintain soil nutrient levels but delayed their decline. More frequent low rate applications of compost or solid manure would probably be more effective in reducing pollution risks while maintaining forage productivity and composition than one large annual manure application.

The four experiments indicate the potential for compatability of conservation farming practices with manure management. According to the agricultural code of practice, manure should be incorporated with 24 hours of application. Experiments 1 and 2 indicate that this is compatible with reduced tillage systems if manure is surface incorporated, a cover crop seeded and the main crop subsequently established using a conservation tillage system. In Experiments 3 and 4, manure was applied to wheat and alfalfa which had very high ground cover ratings. In these experiments, no surface incorporation of manure occurred and relatively low manure application rates were applied to maintain crop productivity while minimizing pollution risks.

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I. Introduction

Land application of manure has long been recognized as a means of increasing soil fertility and improving soil physical properties. However, over the last 20 years, the use of manure in intensive farming systems has caused major pollution problems. Due to the increasing size of livestock operations where animals are confined, manure is often available in larger quantities than needed. Large amounts of manure and poor timing of manure application lead to nitrate pollution of the ground water, streams and lakes by leaching and phosphorus pollution through sediment losses contained in surface runoff.

The combination of intensified livestock rearing and crop production since the early 1960's has created significant water pollution problems. Of primary concern is nitrate losses to the ground water and phosphorus losses to surface waters through runoff and sediment contained in the runoff. While there are no simple solutions to the safe and efficient use of livestock manures, several factors need to be considered when developing strategies to minimize pollution. The major factors affecting the severity of the pollution problem include:

1. *Manure Quantity*: Animal units per land area are too high. This results in manure applications which greatly exceed crop nutrient requirements and subsequently lead to nitrate leaching and buildup of high extractable - P concentrations in the soil.

2. *Manure Distribution*: Because of the low value of livestock manure it is frequently spread in fields located near the storage site in order to reduce handling costs. This leads to excessive nutrient loadings on farms even when total livestock numbers / ha would not indicate a problem.

3. *Manure Type*: Liquid slurries represent a greater challenge compared to straw based solid manure handling systems in terms of reducing the pollution potential of manure. Water, when used as a carrier for manure, increases the risk of surface runoff as well as movement of manure directly through fissures in the soil. Nitrogen in solid manure is much less prone to nitrate leaching or surface runoff because the straw in the manure increases ground cover and absorbs liquids.

4. *Manure Storage*: High livestock densities have created the need for increased manure storage capacity on farms and has resulted in some farms having to apply manure in late fall or early spring when the soil has a high moisture content.

The manure problem is made worse by intensified crop production. These problems include :

1. *Row Crop Production*: extended periods of row crop production frequently occur in Southern Ontario as farmers attempt to grow as much feed as possible for the

livestock on the farm (particularly swine operations). Row cropping tends to provide low residue cover and poor nutrient retention within the farming system.

2. *Soil Degradation*: the loss of soil organic matter associated with intensive crop production has increased the potential for soil erosion and has reduced the soil's ability to retain nitrogen and particulate phosphorus in the surface horizon.

3. *Low Crop Diversity*: Specialized cropping limits the opportunities for manure application within the farm enterprise. This frequently leads to higher than normal application rates. Early seeding practices and late harvests sometimes lead to manure applications under wet conditions. Axle loads of 6 tonnes or more compact the subsoil and yield decreases of 10% can occur for a period of three years or more (Swan et al., 1987).

Rather than viewing manure as an opportunity to close the nutrient cycle within the farm, intensification of livestock and crop production systems is creating in many instances a waste disposal problem. De-intensification strategies need to be developed if a long term solution to most of the pollution problems is to be found. De-intensification does not mean a return to labour intensive practices of the past but rather an integration of the best of the old technologies with the new. Some promising de-intensification strategies for each livestock sector include:

- Beef: forage based finishing of beef through intensive grazing management (Clark, 1989) and heap silage production of high quality forage (Pollock and Proulx, 1986);

- Dairy: intensive pasture management of dairy cattle, potentially in combination with the reintroduction of seasonal dairying for industrial milk production (Zartman, 1991);

- Finishing pigs: feeding lower protein rations by supplementing with alternative amino acid sources to high protein soybean based rations (which increase N loading in the manure);

- Sow Rearing: using unconfined housing systems with straw litter, computerized feeding and summer grazing to reduce the volume of liquid manure produced (Arkinstall, 1991);

- Poultry: switching to a solid manure system using open floors covered with straw rather than battery cages that encourage the use of liquid manure handling systems (Hurnik, 1991).

In addition to dealing with the waste management problem, many of these strategies reduce the cost of livestock rearing and respond to animal welfare concerns. Other basic questions that need to be addressed include using a valuable resource like

water as a vehicle for waste disposal and the need for farm support programs which also take into account ground and surface water quality rather than just economic or performance measures.

While there is a need for restructuring livestock production systems, there is also great need to use the manure generated more efficiently. Of particular concern in Southern Ontario, is the need to develop ways of using various types of manure more efficiently in conservation farming systems in Southern Ontario. A major challenge is not only to identify technologies that minimize P loss in surface runoff but which efficiently recycle nutrients on the farm, contribute to long term soil fertility, result in good agronomic yields and are economically viable.

Quantifying P loss from various manure management strategies could play an important role in helping agriculture reduce its P loading levels into water courses in Southern Ontario. Unfortunately this component of the research project could not be adequately addressed because of problems incurred in the processing of water quality samples from the rainfall simulation experiments.

II. Literature Review

Effect of Conservation Tillage on Runoff

The presence of surface residue is inherent to any conservation tillage system and is the main method by which soil runoff is decreased. No-till has been shown to result in a reduction in the runoff volume (>40%) and soil erosion (>60%) respectively (Angle et al. 1984; Johnson et al., 1979). Consequently reductions in P losses caused by runoff have also been obtained (Angle et al., 1984; McDowell and McGregor, 1984; Langdale et al., 1985). However, reduced tillage tends to increase the concentration of soluble P in the water (Angle et al., 1984; Johnson et al. 1979; Langdale et al. 1985; McDowell and McGregor, 1984). Although such an increase seems to be largely offset by the smaller amount of runoff (McDowell and McGregor, 1984), the impact of conservation tillage on eutrophication will mostly depend on its effect on soluble inorganic P and the biological availability of the sediment P. Compared to conventional tillage, no-till can result in higher concentrations of plant available P in the sediment (Johnson et al., 1979) and sometimes larger losses of soluble P and available P (Johnson et al., 1979; McDowell and McGregor, 1980). In other cases, the decrease in runoff volume due to conservation tillage has offset the increased soluble P concentration (Angle et al., 1984; Langdale et al., 1985). Increased concentration of soluble P in the runoff water from no-tilled fields may result because fertilizer is not incorporated, soluble P is released from residues, not enough sediment is present to absorb P in the solution and possibly that the phosphate supplying capacity of sediments in the runoff is greater (McDowell and McGregor, 1980). On the other hand, the increased P efficiency in some no-till systems should enable reduced P fertilization (Shear and Moshler, 1969). While reductions in total P are obtained in conservation tillage systems, attention must be focused on the losses of soluble P in the runoff water.

Manure Management and Conservation Tillage

Little work exists on manure management in combination with conservation tillage. Greenhouse experiments have shown that sediment-P and water runoff- P losses more than doubled on a sandy loam when part of the chemical fertilizer was replaced by manure. Not only was the concentration of soluble P increased, but so was the solubility of the sediment P (Reddy et al. 1978). One has to keep in mind that the beneficial effect of manure on soil structure was not a factor in this experiment as the tests were run immediately after the soil and manure were mixed. In addition, the use of finely chopped dry manure might have blocked some of the soil pores. In the same experiment, the use of a cover crop was successful in reducing P losses when manure was used. The use of a cover crop in field experiments has been shown to reduce P loss by reducing runoff (Langdale et al., 1985; Pesant et al., 1987).

Although reduced tillage has great potential for reducing erosion, manure management in a complete no-till system gives rise to serious environmental concerns.

Herbicides and fertilizers are often applied on the soil surface which can increase the concentration of pollutants in the runoff. Conservation tillage also requires manure to be left on the soil surface, which is contrary to recommendations found in the agricultural code of practice. A four year study in Quebec found that non-incorporated dairy manure in no-till systems renders weed control very difficult even with heavy herbicide applications, makes it more difficult for corn seedlings to emerge and may result in nitrogen deficiency because a large amount of nitrogen is lost through ammonia volatilization (Weill et al., 1989).

Erosion Control Using Cover Crops and Timed Manure Applications

To use manure successfully and reduce pollution due to runoff, techniques which combine the use of manure with a form of ground cover need to be adopted. Pesant et al. (1987) drilled corn in an alfalfa-timothy sod killed with 4.5 kg/ha of atrazine prior to seeding. Rainfall runoff was reduced by 63% and soil loss by 92%. The increased concentration of soluble P was more than offset by the reduction in runoff volume. The seeding of a cover crop following manure incorporation would protect the soil from erosion. It would require manure application at the end of the summer or the beginning of the fall in order to have enough time for the cover crop to establish before winter. In Ontario, manure increased biomass of oilseed radish while clover growth was reduced (Samson et al., 1990). Oilseed radish is winter killed so a herbicide is not required to control spring growth. Additional advantages of a cover crop are nutrient recycling which reduces leaching losses (Hansen and Rasmussen, 1979) and improved weed control (Kundler, 1985; Samson et al., 1990).

Timing of manure applications also needs to be considered in optimizing manure use. When late summer or early fall manure application are not possible, spring application of manure may be preferable to late fall applications as this would allow the soil to be protected during the most erosion prone period of the year (Dickinson and Pall, 1982). In addition, nitrogen leaching is not as great with a spring manure application compared to a fall application (Culley et al., 1981). Whether the manure is applied in late summer or in the spring, there will be a period when the soil is left unprotected. Reducing the amount of tillage for the incorporation of the manure and leaving a rough soil surface is desirable and would help reduce pollution risks during these times of the year.

Conclusion

Although conservation tillage is an effective means of reducing erosion, it might not be sufficient for reducing P pollution. Deep banding P in no-till systems and possibly reducing the amount of fertilizer used could reduce soluble P losses. If manure has to be applied, the required incorporation results in a bare soil prone to erosion. A catch crop planted after incorporation would reduce erosion and may reduce soluble P losses. There is a need to identify cover crops that can maximize soil cover and minimize soluble P loss from the field during the main runoff periods. It may be especially important to plant cover crops when liquid manure is used in specialized row

crop production as these systems are highly susceptible to erosion problems, have difficulty maintaining soil structure and organic matter levels and are more prone to leaching losses.

III. General Materials and Methods

Forage, Cover Crop (Oil Radish, Rye, Red Clover) and Weed Biomass

Biomass determinations were made by hand shearing a one metre square quadrat area at the ground level. In Experiment 4, forage plants were hand sheared approximately 6 cm above the ground. Weeds and forage were cleared of crop debris and soil before being dried and weighed. Samples processed during the summer months were dried in solar dryers. Fall harvest samples were oven dried at either of the Ontario Ministry of Agriculture and Foods' research stations located in Woodstock or Elora.

Crop Yields

In Experiment 1, corn yields were sampled from the third and sixth rows of each plot. This was done to avoid any variance in yield created by uneven row spacing between the fourth and fifth rows (a 4 row corn planter was used for planting). Cobs were shelled, moistures taken and yields adjusted to a 15.5% moisture basis. In Experiment 2, soybeans were hand harvested from centre rows in each plot. After being threshed with a plot combine, the soybeans were either oven dried or moisture reading were taken and yields adjusted to a 14% moisture basis. In the Experiment 3, a 1.5 m x 1.5 m quadrat was used for harvesting the wheat. The quadrat was centred in the middle of the 2 m x 2 m subplot. Moisture levels were taken after threshing and the yields adjusted to a 12.5% moisture basis.

Ground Cover Measurements

Soil cover was measured using a residue recorder which consisted of 50 knots spaced 10 cm apart. Measurements were made by standing over the rope and looking straight down and counting the number of knots which touched crop residue. Stones, weeds, or crop residue smaller than 1/8" x 1 1/4" were discounted. The rope was stretched diagonally across the plots twice for a total of 100 readings.

Soil, Plant and Water Quality Analysis

Corn: The entire corn plant was harvested at the ground level for nutrient analysis at the 5 leaf stage. At corn silking the mid third of the corn ear leaf was sampled. Soil sampling was performed to a depth of 15 cm on the same day as the corn ear leaves were sampled.

Soybean: Soybean tissue sampling was performed twice: the whole plant was sheared at the ground at 30 days after seeding (d.a.s.) and the top trifoliate leaf was sampled 55 d.a.s. (at flowering).

Wheat: Tissue analysis was performed on wheat flag leaves sampled when the wheat head had fully emerged.

The samples were processed by Analytical Services at the University of Guelph. Soil analyses at the lab are the sodium bicarbonate test for P and ammonium acetate tests for cations. A major problem was incurred with analysis of the P component of the runoff samples when significant runoff occurred. As a result no P runoff data was included in the report for the corn and soybean experiments where significant runoff occurred.

Statistical Analysis

Analyses of variance were carried out on the data using Statistical Analysis System (SAS). When the F-test was significant ($P < .05$), Duncan's multiple range test was used to compare means. In some instances, comparison contrasts were performed to evaluate differences between treatment groupings.

Weather Conditions

Table 1. Corn Heat Unit and Total Precipitation Data from the Elora Research Station

Time Period	Corn Heat Units		Total Precipitation (mm)	
1989		Difference		Difference
May	313	89.9	101.8	24.2
June	607	26.8	130	43.1
July	746	29.5	8.9	-64.1
August	672	4.4	91.7	19.6
September	438	45.0	29	-42.3
October	-		59.4	-6.9
November	-		97.9	32.2
Yearly Total	2776	176	751.9	-84.0
1990		Difference		Difference
May	294	71.3	87.5	9.9
June	589	8.6	84.4	-2.5
July	708	-8.1	60.8	-12.2
August	678	10.2	99.4	27.3
September	418	25.0	67.2	-4.1
October	-		101.4	35.1
November	-		82.6	16.9
Yearly Total	2687	87	899.6	63.7
1991		Difference		Difference
May	394	171	93.6	16.0
June	659	79	26.6	-60.3
July	717	1	140.8	67.8
August	733	65	95.0	22.9
September	439	49	56.6	-14.7
October	-		86.8	20.5
November	-		56.1	-9.6
Yearly Total	2941	341	888.3	52.4

Note: Difference is the amount that Corn Heat Units and total precipitation are above (+) or below (-) the 1951-1980 average value.

IV. Experiments

Experiment 1

Effect of Oilseed Radish, Timing of Manure Application and Tillage System on Nutrient Cycling and Corn Performance (within a Winter Wheat-Corn Sequence)

Introduction

Ott et al. (1982) states that manures alone cannot be used to their optimum without complementary measures such as green manures (that store available N in the fall for subsequent crop growth) and crop rotation (that use species with different rooting depths to facilitate vertical recycling as well as the aeration of the entire soil profile). Based on preliminary REAP-Canada studies on cover crops (Samson et al., 1990) we considered that a midsummer application of manure followed by a fall catch crop of oilseed radish would fit this concept. The oilseed radish is planted after winter wheat and followed by corn. The application of manure to brassica catch crops has been recommended by others (Clement, 1981) to ensure growth of the cover crop and to improve performance of the following crop.

This system of management may have several advantages for improving soil quality and nutrient cycling. Brassica catch crops are efficient N (Derpsch et al., 1986; Hansen and Rasmussen, 1979) and P feeders (Grinsted et al., 1982; Hedley et al., 1982) and contribute to improved aggregate stability (Stokholm, 1979). The ability of brassica plants, and in particular oilseed radish, to rapidly establish a root system, accumulate high concentrations of nutrients, and produce biomass quickly during cool periods is important in reducing nitrate pollution and improving nutrient cycling (Smukalski et al., 1991). In a review paper on nitrate pollution, Strebel et al. (1989) documented numerous European studies which have found that deep rooted brassica species, such as oilseed radish, can reduce nitrate leaching by approximately 50%. Machet and Mary (1989) considered that two processes are involved in reducing nitrate leaching under oilseed radish:

1) the catch crop takes up N in its root zone and acts as a sink for nitrogen as long as the catch crop is alive;
2) the catch crop depletes the soil water content by evapotranspiration, consequently the amount of water that moves down the soil profile is reduced.

The reduction of nitrate leaching through these processes has been well documented in lysimeter studies (Volk and Bell, 1945 (in Meisinger et al., 1991); Bertilsson, 1988). The latter study was very similar to the present one in that relatively high rates of manure N (350 kg N/ha) were applied to soil in August on two soil types. On the sandy soil, the rape cover reduced N leaching losses from 239 kg N/ha to 89 kg/ha and on the clay soil losses were reduced from 156 kg N/ha to 51 kg N/ha (Bertilsson, 1988).

Our hypothesis is that a brassica catch crop seeded in August after manure application will significantly increase ground cover and reduce soil nutrient levels thereby reducing erosion losses, nitrogen leaching and P runoff. This experiment compared the efficiency of late summer manure application to that of spring applied manure in terms of nutrient availability. Spring incorporation of manure has proven successful in supplying adequate nutrients for corn production in reduced tillage systems (Weill et al., 1989). Tillage systems were evaluated in combination with various manure management systems to assess the most efficient management approach for nutrient conservation, pollution control and corn performance.

Table 2. Summary of Experimental Methods and Design

Manure Treatments (Main Plots)		
M1 Summer application + oilseed radish		
M2 Summer application		
M3 Spring application		
Tillage Treatments (Main Plots)		
Fall Moldboard Plowing (M.P.) Fall Chisel Plowing (C.P.) Spring Aerway (A) Zero-Till (Z.T.)		
Fertilization Treatments (subplots)		
No nitrogen added 50 kg N/ha added		
Statistical Design		
Layout	Randomized complete block design with split plot	
Number of main plots	12	
Number of subplots	2	
Number of replications	3	
General Information		
Cooperators	Vernon Ruby Shakespeare, Ont.	Cribit Seeds, West Montrose, Ont.
Previous crop	winter wheat	winter wheat
Soil type	silt loam	sandy loam
Plot size	7 m x 15 m	7 m x 25 m
Manure application rate	liquid swine manure 75,000 l/ha	liquid swine manure 75,000 l/ha
Summer manure application	Aug. 16/89 & Aug. 17/90	Aug. 17/89 & Aug. 17/90
Spring manure application	May 1/90 & May 14/91	May 8/90 & May 17/91
Ground cover measurements (rope knot technique)	Nov. 1/89, May 15/90 Nov. 5/90, May 18/91	Oct. 27/89, May 15/90 Nov. 3/90, May 23/91
Summer manure incorporation and oilseed radish seeding	two cultivations (all plots) & oilradish seeded at 20 kg/ha on Aug. 17/89 & Aug. 22/90	two diskings (all plots) and oilradish seeded at 20 kg/ha on Aug. 18/89 and Aug. 21/90
Extractable P sampling	Aug. 17, Sept. 11, & Oct 26/89 Aug. 22, Sept. 17, & Nov. 2/90	Aug. 18, Sept. 12,& Oct. 25/89 Aug. 22, Sept. 17, & Nov. 2/90

Table 2. Summary of Experimental Methods and Design (Continued)

Activity	Silt Loam Site, Vernon Ruby Farm	Sandy Loam Site, Cribit Seeds Farm
Nitrate sampling (0-20 cm and 20-40 cm depths, 10 cores/plot)	Oct. 26/89 & May 1/90 Nov. 1/90 & May 7/91	Oct. 25/89 & May 3/90 Nov. 2/90 & May 8/91
Cover crop biomass harvest (2 x 1 m^2 quadrat/plot)	Oct. 26/89 & Nov. 1/90, May 8/91	Oct. 25/89 & Nov. 2/90, May 8/91
Fall chisel and moldboard plow	Nov. 1/89 & Nov. 5/90	Oct. 25/89 & Nov. 3/90
Spring tillage	May 7/90 & May 16/91 (2 diskings on chisel and moldboard plots / on Aerway plots 2 passes in 1990 & 1 pass in 1991)	May 9/90 & May 21/91 (1 pass with disk and cultivator on chisel and moldboard plots 1990 +1991/ on Aerway plots 2 passes in 1990 & 1 pass 1991)
Corn Planting	White planter equipped with wavy coulters, no trash whippers	Kinze equipped with trash whippers and 2 Rawson coulters
Corn variety (70,000 p.p./ha)	1990: Northrup King 9163 1991: Pioneer 3921	1990: Pioneer 3902 1991: Pioneer 3929
Corn planting date	May 9/90 & May 16/91	May 11/90 & May 23/91
Contact Herbicide: Round-up 2.5 l/ha	May 10/90 & May 10/91	May 8/90 & May 11/91
Pre or Post Emergent Herbicide (supplemented with hand hoeing)	June 28/90: Atrazine @ 2 kg/ha + Pardner @ 1.0 l/ha June 10/91: Atrazine @ 2 kg/ha	May 15/90: Linuron @ 0.5 kg/ha and Dual @ 2.2 l/ha, May 25/91: Linuron @ 1.0 kg/ha and Dual @ 1.8 l/ha
Fertilizer applications (50 kg/ha)	May 3/90 (urea) May 28/91 (ammonia nitrate)	May 3/90 (urea) May 24/91 (ammonia nitrate)
Corn Harvest	2 x 5 m rows	2 x 5 m rows
Rainfall Simulation	Not performed	Nov./89 and May/90

Table 3. Composition and Total Nutrients in Liquid Swine Manure Application

Manure Composition	Silt Loam Site			Sandy Loam Site		
	% N	% P	% K	% N	% P	% K
Fall 1989	.31	.07	.14	.81	.07	.21
Spring 1990	.54	.10	.22	.53	.16	.17
Fall 1990	.37	.05	.15	.30	.05	.16
Spring 1991	.35	.05	.22	.53	.05	.25
Average Composition	.39	07	.18	.54	.08	.20
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Average Total Nutrients in 75,000 l/ha Application	*293	53	135	*405	60	150

** rough availability of nitrogen is considered to be 50% for spring applied manure and 25% for fall applied manure (OMAF, 1992)*

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Results and Discussion

Ground Cover and Erosion Control

At both sites, the highest fall ground covers were obtained with the systems that following oilseed radish catch crop establishment, received no further fall tillage (Zero-till and Aerway treatments, Table 4). These plots had ground covers approaching 100 %. The extra residue provided by the oilseed radish also increased ground cover significantly in the chisel plow treatments in the fall but little residue remained following secondary tillage and corn planting in the spring. It appeared that the oilseed radish residue cover declined rapidly with any significant amount of spring tillage. On average, only the Aerway and no-till systems could maintain 30% residue cover when used in combination with the oilseed radish catch crop. As expected, ground covers were lowest on moldboard plowed treatments. The chisel plow used at the sandy loam site was equipped with coulters and large sweeps. This may have been responsible for the low ground cover ratings obtained in the chisel plow plots on the sandy loam site. Ground covers might have been improved if less aggressive tillage practices had been used to incorporate the cereal residue and manure after the winter wheat harvest. As well, earlier seeding of the oilseed radish would have enabled greater biomass accumulation resulting in more residual cover in the spring. The main residue left by the oilseed radish catch crop in the spring was the stem. Earlier planting and perhaps lower radish seeding ratings (i.e. 12-15 kg/ha vs. 20 kg/ha used in the present study) would probably have increased stem size and increased spring residue cover over those obtained in this study. From the rainfall simulation studies the main factor that appeared to be controlling erosion rates and runoff volume was the residue cover which resulted from the tillage system used. No-till and Aerway tillage (a non-inversion tillage system) provided highest residue covers and lowest erosion rates (Table 16).

Table 4. Effect of Manure Treatments and Tillage on % Ground Cover

Treatment		Silt Loam Site				Sandy Loam Site			
		Fall 1989	Spring 1990	Fall 1990	Spring 1991	Fall 1989	Spring 1990	Fall 1990	Spring 1991
	M1	6 f	9 e	3 e	4 b	1 f	2 ef	8 e	3 f
Moldboard Plow	M2	4 f	14 e	1 e	5 b	0 f	0 f	0 e	5 f
	M3	1 f	12 e	1 e	8 b	1 f	2 ef	1 e	4 f
	M1	77 c	37 d	54 c	13 b	42 cd	12 def	69 b	8 ef
Chisel Plow	M2	59 d	62 c	34 d	20 b	18 e	18 cde	45 c	13 e
	M3	52 e	40 d	31 d	11 b	22 e	25 cd	50 c	14 e
	M1	100 a	58 c	98 a	80 a	96 a	22 cd	94 a	38 d
Aerway	M2	91 b	69 bc	67 bc	71 a	80 bc	18 cde	70 b	40 cd
	M3	91 b	60 c	70 bc	67 a	67 b	29 bcd	86 b	48 ab
	M1	99 a	77 ab	96 a	65 a	97 a	52 a	96 a	52 a
Zero-Till	M2	91 b	88 a	58 bc	79 a	56 b	45 ab	71 b	44 bc
	M3	90 b	85 a	75 b	75 a	37 d	31 bc	75 b	54 a
C.V.		18.7%	13.1 %	22.3%	29.1%	11.7 %	44.1 %	13.3%	14.3%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Oilseed Radish Above Ground Biomass and Nutrient Accumulation

In both years fall biomass production was higher on the silt loam site than the sandy loam site (Table 5). On average, approximately 100 kg/ha of N was taken up in the above ground biomass of the oilseed radish. In 1989, the N content of the oilseed radish was very high on the sandy loam site which was likely due to the very high N level applied in the form of liquid manure (Table 3). The oilseed radish N content and soil nitrates (Table 7) were lower at both sites in 1990. Significant nitrogen loss may have occurred before the oilseed radish had a root system large enough to capture all the manure nutrients, particularly on the sandy loam in the fall of 1990. At both sites, heavy rains fell immediately after the manure application. As a result the manure could not be incorporated within 24 hours of application as had been done in 1989.

Phosphorus uptake by the oilseed radish ranged from 10-16 kg P/year in the above ground biomass at the time of fall sampling (Table 5). Although this was much smaller than N and K uptake, it may have been significant as the soil P levels were low in the study (See Table 11 for soil P levels in zero-till plots). Potassium uptake on the silt loam site was approximately one third higher than on the sandy loam site. On the silt loam site, potassium content of the oilseed radish averaged 5%. This translates into approximately 150 kg K/ha being taken up by the time the late fall sampling was performed each year.

Table 5. Nutrient Content in the Above Ground Biomass of Oilseed Radish

Treatment	Biomass (kg/ha)	Nutrient Analysis			Nutrient Uptake (kg/ha)		
		% N	% P	% K	N	P	K
Fall Analysis Silt Loam							
1989-90	3152	3.19	0.42	4.7	100	13	148
1990-91	3015	2.83	0.52	5.4	85	16	162
Fall Analysis Sandy Loam							
1989-90	2624	4.82	0.56	3.8	126	15	100
1990-91	2479	2.88	0.39	3.7	71	10	93
Spring Analysis Silt Loam							
1989-90	-	1.63	0.27	0.3	-	-	-
1990-91	898	1.52	0.30	0.3	13	3	3
Spring Analysis Sandy Loam							
1989-90	-	1.47	0.25	0.2	-	-	-
1990-91	500	1.26	0.22	0.2	6	1	1

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	M1	77 c	37 d	54 c	13 b	42 cd	12 def	69 b	8 ef
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	M3	52 e	40 d	31 d	11 b	22 e	25 cd	50 c	14 e
	M1	100 a	58 c	98 a	60 a	96 a	22 cd	94 a	36 d
Aerway	M2	91 b	69 bc	67 bc	71 a	50 bc	19 cde	70 b	40 cd
	M3	91 b	60 c	70 bc	67 a	57 b	29 bcd	66 b	48 ab
	M1	99 a	77 ab	96 a	65 a	97 a	52 a	96 a	52 a
Zero-Till	M2	91 b	88 a	58 bc	79 a	56 b	45 ab	71 b	44 bc
	M3	90 b	85 a	75 b	75 a	37 d	31 bc	75 b	54 a
C.V.		18.7%	13.1 %	22.3%	29.1%	11.7 %	44.1 %	13.3%	14.3%

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1990-91	500	1.26	0.22	0.2	6	1	1

Effects of Oilseed Radish on Soil Moisture and Soil Nitrates Levels

There was considerably more rainfall in the fall of 1990 than in 1989. As a result soil moisture levels were higher at both sites in 1990 than in 1989. When soil moisture measurements were made in October of 1989, soil moisture in the oilseed radish plots was significantly lower than the other treatments. When the data was analyzed an interaction was found at the sandy loam site. Soil moisture levels were lowered by the oilseed radish treatment at the 20-40 cm sampling depth (Table 6). The differences were evident at the time of sampling as the dry soil conditions on the oilseed radish plots made soil sampling difficult at the 20-40 cm depth. The 20-40 cm depth was also the depth at which nitrate levels were reduced most (Table 7). In 1990, the oilseed radish had no effect on soil moisture levels. This was probably due to the high rainfall which was received during the fall of 1990. As well, oilseed radish biomass was lower in the fall of 1990 which likely reduced evapotranspiration as compared to 1989.

Table 6. Effect of Oilseed Radish and Liquid Manure on Fall Soil Moisture

Treatment	Soil Moisture (%) Fall 1989			Soil Moisture (%) Fall 1990	
	Silt Loam 0-40 cm soil depth	Sandy Loam 0-20 cm soil depth	Sandy Loam 20-40cm soil depth	Silt Loam 0-40 cm soil depth	Sandy Loam 0-40 cm soil depth
Summer manure + oilradish	16.2	16.9	12.3 b	22.4	19.5
Summer manure	18.4	18.6	16.3 a	21.2	19.7
Control	18.4	17.2	15.3 a	21.2	19.5
C.V.	7.2%	8.6%	7.0%	6.3%	7.3 %

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

In both years and on both soil types, oilseed radish was effective in reducing soil nitrates compared to the summer manured treatment which had no catch crop (Table 7). Perhaps most surprising was that at all 4 test sites, the oilseed radish plots had nitrates levels as low as the control plots which had not received the slurry application. The reduction in soil nitrates was most dramatic at the 20-40 cm depth in early November 1990 when soil nitrate levels approached zero. While there may be concern over loss of nitrates during the winter, studies have indicated that nutrients accumulated in the stubble, for the most part, do not leach during the winter as mineralization processes are largely reduced under cold temperatures (Buchner, 1987 in Smukalski et al., 1991).

Probably of greater concern is nitrate loss prior to the development of the catch crop. In 1990, heavy rains fell immediately after the manure application. They appeared to have caused a significant loss of nitrates from the soil surface horizon, particularly on the sandy loam site. This can be seen by:

1) the generally lower levels in the soil in the fall of 1990;
2) lower nitrate levels at the 0-20 cm depth than at the 20-40 cm level on non cover cropped plots.

The nitrate levels at the sandy loam site in the fall of 1989 stood out as being very high even on plots in which no manure was applied. The field was in alfalfa in 1988 and approximately 100 kg N/ha was applied to the winter wheat crop in the spring of 1989. As the 1988-89 period was relatively dry it would appear that significant residual nitrogen remained in the field from previous cropping practices. The nitrogen application probably was not required for the wheat crop.

Table 7. Effect of Oilseed Radish and Manure on Soil Nitrogen in the Zero-Till Plots

Treatment (sampled on zero-till plots)	Silt Loam 0-20 cm	Silt Loam 20-40 cm	Sandy Loam 0-20 cm	Sandy Loam 20-40 cm
Nitrate (NO_3)-N (ppm)				
Fall 1989				
Summer manure + oilseed radish	7.2 b	4.1	19.6 b	12.6 b
Summer manure	11.2 a	7.7	63.4 a	31.3 a
Control (no manure or catch crop)	6.1 b	4.5	17.9 b	13.5 b
C.V.	13.5%	30.2%	27.2%	27.9%
Fall 1990				
Summer manure + oilseed radish	3.4 b	0.3	2.1 b	0.0 b
Summer manure	7.6 a	8.1	6.8 a	11.0 a
Control (no manure or catch crop)	3.0 b	7.4	1.7 b	0.9 b
C.V.	25.2%	73.3%	46.9%	36.6%
Ammonia (NH_4)-N (ppm)				
Fall 1989				
Summer manure + oilseed radish	1.6	1.5	5.2	8.9
Summer manure	1.7	1.9	4.5	4.5
Control (no manure)	2.5	1.9	6.2	4.4
C.V.	56.1%	33.0%	41.7%	89.0%
Fall 1990				
Summer man. + oilseed radish	4.9	7.7	4.8	7.1
Summer manure	5.2	3.6	7.0	5.3
Control (no manure)	6.2	11.3	4.6	7.4
C.V.	34.9%	56.2%	44.1%	24.6%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Perhaps a better way to reduce leaching losses (particularly on the sandy soil) would be to apply the liquid manure to an established oilseed radish crop in September. Eliminating the need to apply manure prior to oilseed radish seeding would also enable the farmer to establish the green manure earlier. Earlier seeding would increase biomass accumulation and hence reduce nitrate leaching by increasing evapotranspiration and N uptake (Steenvoorden, 1989). While volatilization losses may be a concern when manure is not incorporated soon after field application, ammonia losses might be reduced as temperatures are cooler in September and wind speed at the soil surface would be lowered by the growing oilseed radish. This would reduce the threat of a drying wind and warm temperatures that favor volatilization. Applying manure to a growing cover crop would also resolve another major problem which was experienced in 1990, the timeliness of field operations. The manure application needs to be quickly followed by incorporation and then seeding of the oilseed radish. With

the wet weather conditions that were experienced in mid-August, field operations (manure application, cultivation, and oilseed radish seeding) were performed when the field was not completely dry and ruts were made by the wheels in some areas. Another benefit of seeding oilseed radish prior to liquid manure application is that cultivation prior to oilseed radish establishment would break fissures that provide paths for the liquid manure to move rapidly into tile drains as reported by Dean and Foram (1990).

Fall Soil P Levels

Assessing the effects of oilseed radish and manure application on soil P proved difficult as 3 of 4 sites had relatively low P levels. The low P levels may have allowed small field variability to mask treatment effects on soil P as the coefficients of variation were high where soil P levels were lowest. The main effect that was observed was that soil P was increased at some of the sites after manure application in mid August (Table 8). Sampling was performed at two later fall dates but no further treatment effects were observed. Sampling on the same plots in the following year to a depth of 15 cm indicated that in some instances, that the trends observed the previous fall were reversed; i.e. soil P levels that were highest in the summer manured plots were now lower than in the spring manure plots.

Table 8. Effect of Summer Manure Loading Activity on Soil P Levels in late August

Treatments	Silt Loam		Sandy Loam	
Zero-Till Plots	0-10 cm soil depth	10-20 cm soil depth	0-10 cm soil depth	10-20 cm soil depth
Soil P (ppm) Fall 1989				
Summer man. + oilseed radish (Z1)	22.3	17.7	15.3	6.0
Summer manure (Z2)	18.0	13.3	14.7	7.7
Control (no manure until spring) (Z3)	12.0	11.0	6.3	5.0
C.V.	34.1%	29.7%	26.5%	38.6%
Contrasts Z1, Z2 vs. Z3	-	-	*	-
Soil P (ppm) Fall 1990				
Summer man. + oil seed radish	30.7	24.7	10.3	8.3
Summer manure	28.0	19.7	11.0	6.7
Control (no manure until spring)	24.7	18.3	12.0	8.3
C.V.	13.4%	7.2%	22.2%	39.9%
Contrast Z1, Z2 vs. Z3		*	-	-

Note: +, *,** indicates contrasts significant at the .10, .05 and .01 level.

P Nutrition in Corn

Spring application of liquid manure resulted in higher soil P levels at two of four sites (Table 9). On the silt loam, corn plants harvested at the 5 leaf stage tended to have higher N and P contents where spring manure was applied. Oilseed radish seeded in the fall of 1989 had a pronounced effect on reducing P uptake on the silt loam site in 1990. Plots containing oilseed radish residue were readily identifiable as the corn was purple early in the season. Some of the corn leaf tips remained purple until corn tasselling. A tissue analysis of winter killed oilseed radish residue in the spring of 1990 indicated that it contained 1.6%N (Table 5). This was within the nitrogen range (1.2-1.8%N) that Breland (1990) considered will cause nutrient immobilization in the form of microbial biomass. While this may be one reason P uptake was reduced, a second may be that oilseed radish absorbed a significant quantity of P (13 kg in the aboveground biomass on the silt loam site in the fall of 1989) and that release was slow. Spring analysis of the oilseed radish residue indicated approximately 15% of the P remained in the oilseed radish residue (Table 5). The combination of slow P release from the residue and microbial immobilization of soil P as a result of the high C to N ratio of the residue might have contributed to the reduced P availability. This process may be very similar to that believed to be associated with the N immobilization effect of a rye cover crop in Experiment 2 (i.e. N moves into the cover crop from the soil in the spring but the N is not released quickly after the mature cover crop is killed. The remaining soil N is immobilized by the microbial biomass as it breaks down the high carbon mulch. This further accentuates the N tie-up.

Tillage did not seem to play a significant role in reducing the effect of the oilseed radish. As well the P immobilization appeared to be eliminated by the time ear leaf sampling was performed (Table 12). This transitory immobilization of P by the oilseed radish was also observed in an earlier study (Samson et al., 1991). Slow growth of no-till corn early in the season following oilseed radish has also been reported in Brazil (Derpsch et al., 1986). The other major trend that occurred at all study sites when contrasts were performed, was that the zero-tilled corn appeared to have improved P nutrition compared to the more aggressive tillage systems (moldboard and chisel plow) when measured at the 5 leaf stage (Table 9).

By ear leaf sampling, the strongest effect appeared to be at the silt loam site where spring applied manure provided the highest P levels in the ear leaf (Table 12). As well the oilseed radish plots in 1991 had higher ear leaf P levels than those receiving summer manure only. On the sandy loam site, the no-till treatments continued to have a higher P concentration in the plant tissue than either the moldboard or chisel plowed treatments. While it is interesting to note treatment effects at ear leaf sampling, they are not as appropriate to assess P nutrition effects on corn yield as is whole plant sampling of corn at the 4-6 leaf stage (Barry et al., 1989).

Table 9. Effect of Oilseed Radish, Manure and Tillage on Soil P and Corn Nutrients at the 5 Leaf Stage

Treatment		Silt Loam Site			Sandy Loam Site		
		Soil P	5 Leaf Stage Corn		Soil P	5 Leaf Stage Corn	
		ppm	% N	% P	ppm	% N	% P
1990	M1	10 c	4.00 bc	0.282 cd	9	3.78	0.207
Moldboard Plow	M2	10 c	3.97 bc	0.288 bcd	8	3.83	0.220
(MP)	M3	14 bc	4.20 a	0.322 abc	8	3.98	0.252
	M1	9 c	3.88 c	0.252 d	8	3.83	0.235
Chisel Plow	M2	10 c	3.98 bc	0.308abcd	8	3.92	0.232
(CP)	M3	20 a	4.15 ab	0.333 abc	8	3.95	0.240
	M1	12 c	3.97 bc	0.287 bcd	8	3.95	0.253
Aerway	M2	10 c	3.97 bc	0.307abcd	10	4.00	0.275
(A)	M3	18 ab	4.10 ab	0.348 ab	8	4.03	0.257
	M1	10 c	3.85 c	0.280 cd	6	4.03	0.272
Zero-Till	M2	10 c	3.90 c	0.355 a	8	4.02	0.270
(ZT)	M3	17 ab	4.02 bc	0.357 a	8	3.95	0.238
C.V.		21.0 %	2.5 %	10.9 %	25.6%	3.3%	11.3%
M1 vs. M2		-	-	**	-	-	-
M1 vs. M3		**	**	**	-	+	-
M2 vs. M3		**	**	+	-	-	-
MP vs. CP		-	-	-	-	-	*
MP vs. A		-	-	-	-	-	-
MP vs. ZT		-	+	-	-	-	-
CP vs. A		-	-	-	-	-	-
CP vs. ZT		-	**	*	-	+	*
A vs. ZT		-	+	*	-	-	-
1991	M1	22	3.87 ab	0.367	22	4.19	0.384 c
Moldboard Plow	M2	23	3.77 ab	0.377	13	3.99	0.387 c
(MP)	M3	29	3.92 a	0.355	22	3.98	0.392 c
	M1	25	3.83 ab	0.395	15	3.88	0.382 c
Chisel Plow	M2	28	3.58 bc	0.378	19	3.90	0.394 bc
(CP)	M3	30	3.93 a	0.367	19	4.27	0.415 bc
	M1	26	3.67 ab	0.377	12	4.18	0.417 bc
Aerway	M2	25	3.32 c	0.377	19	4.04	0.434 ab
(A)	M3	27	3.90 a	0.385	29	4.11	0.393 bc
	M1	25	3.68 ab	0.400	16	3.80	0.420 abc
Zero-Till	M2	28	3.37 c	0.385	20	4.02	0.457 a
(ZT)	M3	26	3.82 ab	0.373	20	3.99	0.407 bc
C.V.		14.2 %	4.2 %	4.2 %	34.2%	4.8 %	5.2 %
M1 vs. M2		-	**	-	-	-	+
M1 vs. M3		*	+	+	*	-	-
M2 vs. M3		-	**	-	*	-	+
MP vs. CP		+	-	-	-	-	-
MP vs. A		-	**	-	-	-	+
MP vs. ZT		-	**	+	-	-	**
CP vs. A		-	+	-	-	-	+
CP vs. ZT		-	*	-	-	-	**
A vs. ZT		-	-	-	-	+	-

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Note 2. +,*, ** indicates contrasts significant at the .10, .05 and .01 level

Table 9. Effect of Oilseed Radish, Manure and Tillage on Soil P and Corn Nutrients at the 5 Leaf Stage

Treatment		Silt Loam Site			Sandy Loam Site		
		Soil P	5 Leaf Stage Corn		Soil P	5 Leaf Stage Corn	
		ppm	% N	% P	ppm	% N	% P
1990	M1	10 c	4.00 bc	0.282 cd	9	3.78	0.207
Moldboard Plow	M2	10 c	3.97 bc	0.288 bcd	8	3.83	0.220
(MP)	M3	14 bc	4.20 a	0.322 abc	8	3.98	0.262
	M1	9 c	3.88 c	0.252 d	8	3.83	0.235
Chisel Plow	M2	10 c	3.98 bc	0.308abcd	8	3.92	0.232
(CP)	M3	20 a	4.15 ab	0.333 abc	8	3.95	0.240
	M1	12 c	3.97 bc	0.287 bcd	8	3.95	0.253
Aerway	M2	10 c	3.97 bc	0.307abcd	10	4.00	0.275
(A)	M3	18 ab	4.10 ab	0.348 ab	8	4.03	0.257
	M1	10 c	3.85 c	0.280 cd	6	4.03	0.272
Zero-Till	M2	10 c	3.90 c	0.355 a	8	4.02	0.270
(ZT)	M3	17 ab	4.02 bc	0.357 a	8	3.95	0.238
C.V.		21.0 %	2.5 %	10.9 %	25.6%	3.3%	11.3%
M1 vs. M2		-	-	**	-	-	-
M1 vs. M3		**	**	**	-	+	-
M2 vs. M3		**	**	+	-	-	-
MP vs. CP		-	-	-	-	-	*
MP vs. A		-	-	-	-	-	-
MP vs. ZT		-	+	-	-	-	-
CP vs. A		-	-	-	-	-	-
CP vs. ZT		-	**	*	-	+	*
A vs. ZT		-	+	*	-	-	-
1991	M1	22	3.87 ab	0.387	22	4.19	0.384 c
Moldboard Plow	M2	23	3.77 ab	0.377	13	3.88	0.387 c
(MP)	M3	29	3.92 a	0.366	22	3.98	0.382 c
	M1	25	3.83 ab	0.395	15	3.88	0.382 c
Chisel Plow	M2	28	3.58 bc	0.378	19	3.90	0.394 bc
(CP)	M3	30	3.93 a	0.367	19	4.27	0.415 bc
	M1	26	3.67 ab	0.377	12	4.18	0.417 bc
Aerway	M2	25	3.32 c	0.377	18	4.04	0.434 ab
(A)	M3	27	3.90 a	0.385	28	4.11	0.393 bc
	M1	25	3.68 ab	0.400	16	3.80	0.420 abc
Zero-Till	M2	28	3.37 c	0.385	20	4.02	0.457 a
(ZT)	M3	26	3.82 ab	0.373	20	3.99	0.407 bc
C.V.		14.2 %	4.2 %	4.2 %	34.2%	4.8 %	5.2 %
M1 vs. M2		-	**	-	-	-	+
M1 vs. M3		*	+	+	*	-	-
M2 vs. M3		-	**	-	*	-	+
MP vs. CP		+	-	-	-	-	-
MP vs. A		-	**	-	-	-	+
MP vs. ZT		-	**	+	-	-	**
CP vs. A		-	+	-	-	-	+
CP vs. ZT		-	*	-	-	-	**
A vs. ZT		-	-	-	-	+	-

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Note 2. +,*, ** indicates contrasts significant at the .10, .05 and .01 level

Effect of Manure and Oilseed Radish on Spring Nitrate Levels

The zero-till plots which had been sampled in the fall for nitrates were again sampled in the spring to determine if the N in the cover crop had been released to the corn crop (Table 10). In both years, soil nitrate sampling was performed in early May prior to spring field operations. As well, oilseed radish plots which had been fall chisel and moldboard plowed were also sampled to determine if tillage was affecting soil nitrate levels early in the season. Overall the data indicated that oilseed radish was effective in keeping nitrates in the surface soil horizon (0-20 cm) and that the combination of oilseed radish following manure application and fall tillage resulted in the highest soil nitrate levels. The nitrogen conserving effect of the oilseed radish appeared to be most evident in the spring of 1991. It is likely that the wet fall period of 1990 contributed to a greater loss of nitrates in non- cover cropped treatments.

Table 10. Effect of Oilseed Radish, Manure and Tillage System on Soil N in the Spring

Treatments	Silt Loam		Sandy Loam	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Nitrate N (NO_3-N), ppm				
May 1990				
M.P. : Summer manure + oilradish	12.2	6.7	20.8 a	9.0
C.P. : Summer manure + oilradish	10.3	5.6	13.7 b	10.0
Z.T. : Summer manure + oilradish	7.1	5.7	9.2 b	5.1
Z.T. : Summer manure	6.1	4.1	8.6 b	13.0
Z.T. : Control (no manure)	4.6	3.5	7.4 b	9.0
C.V.	35.2%	29.8%	27.0%	46.2%
May 1991				
M.P. : Summer manure + oilradish	12.7 a	6.6 a	5.2 a	3.3
C.P. : Summer manure + oilradish	9.4 b	4.2 ab	4.6 a	2.8
Z.T. : Summer manure + oilradish	5.8 c	4.2 ab	4.6 a	2.3
Z.T. : Summer manure	2.5 d	1.6 bc	3.3 b	3.7
Z.T. : Control (no manure)	2.2 d	1.2 c	3.0 b	2.0
C.V.	16.6%	38.3%	13.5%	9.1%
Ammonia-N (NH_4-N), ppm				
May 1990				
M.P. : Summer manure + oilradish	3.3 a	2.5	1.1	1.2
C.P. : Summer manure + oilradish	1.9 b	1.5	1.5	1.8
Z.T. : Summer manure + oilradish	1.7 b	2.2	2.2	1.5
Z.T. : Summer manure	2.0 b	1.3	2.2	1.3
Z.T. : Control (no manure)	1.4 b	1.3	1.5	3.2
C.V.	23.8%	30.6%	61.1%	67.7%
May 1991				
M.P. : Summer manure + oilradish	1.8	1.6	2.2	1.2
C.P. : Summer manure + oilradish	2.6	1.5	2.4	1.7
Z.T. : Summer manure + oilradish	2.6	1.6	1.9	2.2
Z.T. : Summer manure	1.4	2.7	1.9	2.0
Z.T. : Control (no manure)	1.6	1.5	2.7	1.5
C.V.	50.6%	69.8%	34.3%	88.2%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

In the summer manured zero-till plots, soil nitrate levels measured in the spring were low (Table 10). However, ear leaf N and corn yields measured later in the season on these plots (receiving no additional spring nutrient source) were higher than would have been expected based on the N soil test (Tables 11 & 14). Research at the University of Guelph suggests that approximately 19 ppm of nitrate is required in the top 30 cm for their to be no requirement for any additional fertilizer N (Kachanoski, 1991). It is likely that early spring nitrate sampling on the no-till plots underestimates the N that is available to corn for several reasons: mineralization increases with warmer soil temperatures and it is likely that no-till management delays this process. As well, significant amounts of N are in an organic form when manure is used. Nitrogen soil testing prior to corn planting underestimates N release from this form. Later spring sampling for soil nitrate levels would probably have provided much higher nitrate levels from all treatments and have been a more effective indicator of N fertilizer requirements for manured and no-till treatments.

Ear Leaf N

Spring application of liquid manure appeared to be the most effective treatment for supplying nitrogen to the corn crop. In the spring applied manure treatments, the application of 50 kg fertilizer N had no significant effect on ear leaf N content (Table 11). In three of the four study sites, the application of 75,000 l/ha of liquid swine manure produced high ear leaf N contents (greater than 3.4%) without additional fertilizer N. The sandy loam site in 1991 had the lowest ear leaf N content. Summer applied liquid manure generally resulted in lower ear leaf N measurements than the spring applied liquid manure, particularly on the silt loam sites. On the summer applied manure treatments in 1991, oilseed radish significantly increased ear leaf N content of the corn at both sites. This would be expected following the relatively wet fall of 1990 in which downward movement of nitrates was observed in the non-catch cropped treatments (Table 7). No testing of ear leaf N at the 50 kg N/ha level was done at the sandy loam site in 1990 because it was clear that the field was abundantly supplied with nitrates because of the previous field history (legume forage stand and high N fertilization). In the summer applied manure treatments, increasing tillage intensity appeared to increase ear leaf N content. The same trend was observed with the soil nitrate data early in the season (Table 10).

Ear Leaf K

All sites tended to indicate higher ear leaf potassium levels with increased tillage intensity (Table 12). The tillage effect was most pronounced on the sandy loam site where ear leaf potassium levels were lower. In both years at the sandy loam site, some of the treatments had ear leaf potassium levels either below or at the critical level of 1.20% (OMAF, 1990). At all four of the study sites the highest ear leaf potassium level was associated with the oilseed radish plot which had been fall moldboard plowed. At three of the study sites, the lowest ear leaf potassium level was found

Table 11. Effect of Oilseed Radish, Manure and Tillage System on Ear Leaf N at Silking

Treatment		Silt Loam Site % N		Sandy Loam % N	
		0 kg N/ha	50 kg N/ha	0 kg N/ha	50 kg N/ha
1990	M1	3.45 abc	3.58	3.42	-
Moldboard Plow	M2	3.35 abc	3.52	3.60	-
(MP)	M3	3.55 ab	3.57	3.83	-
	M1	3.17 cd	3.38	3.68	-
Chisel Plow	M2	3.17 cd	3.40	3.63	-
(CP)	M3	3.52 ab	3.60	3.42	-
	M1	3.33 abc	3.45	3.60	-
Aerway	M2	3.17 cd	3.60	3.63	-
(A)	M3	3.53 ab	3.47	3.65	-
	M1	3.00 d	3.48	3.52	-
Zero-Till	M2	3.23 bcd	3.52	3.65	-
(ZT)	M3	3.63 a	3.52	3.53	-
C.V.		5.2%	3.7%	4.1 %	-
M1 vs. M2		-	-	-	-
M1 vs. M3		**	-	-	-
M2 vs. M3		**	-	-	-
MP vs. CP		-	-	-	-
MP vs. A		-	-	-	-
MP vs. ZT		-	-	-	-
CP vs. A		-	-	-	-
CP vs. ZT		-	-	-	-
A vs. ZT		-	-	-	-
1991	M1	3.05 b	3.46 abc	3.08	3.23 ab
Moldboard Plow	M2	3.04 b	3.35 bc	3.20	3.27 ab
(MP)	M3	3.66 a	3.51 abc	3.19	3.16 abc
	M1	3.11 b	3.40 abc	3.14	3.23 abc
Chisel Plow	M2	2.70 c	3.30 cd	2.97	3.09 bc
(CP)	M3	3.65 a	3.51 abc	3.14	3.15 abc
	M1	2.89 bc	3.53 abc	3.17	3.30 a
Aerway	M2	2.87 c	3.11 d	2.96	3.13 bc
(A)	M3	3.63 a	3.63 a	3.15	3.23 abc
	M1	2.98 bc	3.37 bc	3.01	3.11 bc
Zero-Till	M2	2.79 bc	3.10 d	2.99	3.02 c
(ZT)	M3	3.61 a	3.59 a	3.15	3.08 bc
C.V.		5.5%	3.6%	3.7%	4.0%
M1 vs. M2		**	**	-	*
M1 vs. M3		**	*	-	*
M2 vs. M3		**	**	*	-
MP vs. CP		-		-	-
MP vs. A		+		-	-
MP vs. ZT		-		+	**
CP vs. A		-		-	-
CP vs. ZT		-		-	-
A vs. ZT		-		-	**

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test

Note 2. +,*,** indicates contrasts significant at the .10, .05 and .01 level

Table 11. Effect of Oilseed Radish, Manure and Tillage System on Ear Leaf N at Silking

Treatment		Silt Loam Site % N		Sandy Loam % N	
		0 kg N/ha	50 kg N/ha	0 kg N/ha	50 kg N/ha
1990	M1	3.45 abc	3.58	3.42	-
Moldboard Plow	M2	3.35 abc	3.52	3.60	-
(MP)	M3	3.55 ab	3.57	3.63	-
	M1	3.17 cd	3.38	3.68	-
Chisel Plow	M2	3.17 cd	3.40	3.63	-
(CP)	M3	3.52 ab	3.60	3.42	-
	M1	3.33 abc	3.45	3.60	-
Aerway	M2	3.17 cd	3.50	3.63	-
(A)	M3	3.53 ab	3.47	3.65	-
	M1	3.00 d	3.48	3.52	-
Zero-Till	M2	3.23 bcd	3.52	3.65	-
(ZT)	M3	3.63 a	3.52	3.53	-
C.V.		5.2%	3.7%	4.1 %	-
M1 vs. M2		-	-	-	-
M1 vs. M3		**	-	-	-
M2 vs. M3		**	-	-	-
MP vs. CP		-	-	-	-
MP vs. A		-	-	-	-
MP vs. ZT		-	-	-	-
CP vs. A		-	-	-	-
CP vs. ZT		-	-	-	-
A vs. ZT		-	-	-	-
1991	M1	3.06 b	3.46 abc	3.06	3.33 ab
Moldboard Plow	M2	3.04 b	3.35 bc	3.20	3.27 ab
(MP)	M3	3.65 a	3.51 abc	3.18	3.15 abc
	M1	3.11 b	3.40 abc	3.14	3.23 abc
Chisel Plow	M2	2.70 c	3.30 cd	2.97	3.09 bc
(CP)	M3	3.65 a	3.51 abc	3.14	3.15 abc
	M1	2.99 bc	3.53 abc	3.17	3.39 a
Aerway	M2	2.87 c	3.11 d	2.98	3.13 bc
(A)	M3	3.63 a	3.63 a	3.15	3.23 abc
	M1	2.98 bc	3.37 bc	3.01	3.11 bc
Zero-Till	M2	2.79 bc	3.10 d	2.99	3.02 c
(ZT)	M3	3.61 a	3.59 a	3.15	3.08 bc
C.V.		5.5%	3.6%	3.7%	4.0%
M1 vs. M2		**	**	-	*
M1 vs. M3		**	*	-	*
M2 vs. M3		**	**	*	-
MP vs. CP		-		-	-
MP vs. A		+		-	-
MP vs. ZT		-		+	**
CP vs. A		-		-	-
CP vs. ZT		-		-	-
A vs. ZT		-		-	**

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test

Note 2. +,*, ** indicates contrasts significant at the 10, .05 and .01 level

Table 12. Effect of Manure, Oil Radish and Tillage System on Ear Leaf P and K

Treatment		Silt Loam Site		Sandy Loam Site	
		% P	% K	% P	% K
1990	M1	0.344 abc	2.17	0.318	1.85 a
Moldboard Plow	M2	0.340 abcd	2.13	0.330	1.65 ab
(MP)	M3	0.349 a	2.09	0.327	1.49 bc
	M1	0.328 d	2.03	0.327	1.45 bc
Chisel Plow	M2	0.336 bcd	1.98	0.331	1.44 bc
(CP)	M3	0.348 ab	1.97	0.317	1.35 bc
	M1	0.333 cd	1.94	0.323	1.43 bc
Aerway	M2	0.336 bcd	2.04	0.320	1.48 bc
(A)	M3	0.343 abc	1.90	0.325	1.42 bc
	M1	0.330 d	2.02	0.315	1.20 c
Zero-Till	M2	0.333 cd	2.07	0.325	1.40 bc
(ZT)	M3	0.348 ab	2.03	0.318	1.38 bc
C.V.		3.6 %	5.5 %	3.2 %	11.4 %
M1 vs. M2		-	-	-	-
M1 vs. M3		**	-	-	-
M2 vs. M3		**	+	-	-
MP vs. CP		-	**	-	**
MP vs. A		-	**	-	-
MP vs. ZT		+	*	-	-
CP vs. A		-	-	-	**
CP vs. ZT		-	-	-	**
A vs. ZT		-	*	-	-
1991	M1	0.337 bc	1.99	0.317 bc	1.82
Moldboard Plow	M2	0.342 b	1.88	0.319 bc	1.48
(MP)	M3	0.360 ab	1.93	0.316 bc	1.46
	M1	0.336 bc	1.82	0.320 bc	1.63
Chisel Plow	M2	0.323 cd	1.93	0.303 c	1.31
(CP)	M3	0.350 ab	1.94	0.333 abc	1.19
	M1	0.340 bc	1.82	0.352 a	1.17
Aerway	M2	0.313 d	1.79	0.334 ab	1.16
(A)	M3	0.362 a	1.90	0.329 abc	1.44
	M1	0.340 bc	1.75	0.353 a	0.98
Zero-Till	M2	0.316 d	1.80	0.345 ab	1.01
(ZT)	M3	0.352 ab	1.88	0.338 ab	1.26
C.V.		4.0 %	4.5 %	4.6 %	11.3 %
M1 vs. M2		**	-	-	-
M1 vs. M3		**	+	-	-
M2 vs. M3		**	-	-	-
MP vs. CP		-		-	-
MP vs. A		-	*	*	*
MP vs. ZT		-	**	**	**
CP vs. A		-	-	*	-
CP vs. ZT		-	+	**	**
A vs. ZT		-	-	-	-

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Note 2. +,*, ** indicates contrasts significant at the .10, .05 and .01 level

Table 12. Effect of Manure, Oil Radish and Tillage System on Ear Leaf P and K

Treatment		Silt Loam Site		Sandy Loam Site	
		% P	% K	% P	% K
1990	M1	0.344 abc	2.17	0.318	1.85 a
Moldboard Plow	M2	0.340 abcd	2.13	0.330	1.65 ab
(MP)	M3	0.349 a	2.09	0.327	1.49 bc
	M1	0.328 d	2.03	0.327	1.45 bc
Chisel Plow	M2	0.336 bcd	1.98	0.331	1.44 bc
(CP)	M3	0.348 ab	1.97	0.317	1.35 bc
	M1	0.333 cd	1.94	0.323	1.43 bc
Aerway	M2	0.336 bcd	2.04	0.320	1.46 bc
(A)	M3	0.343 abc	1.90	0.325	1.42 bc
	M1	0.330 d	2.02	0.315	1.20 c
Zero-Till	M2	0.333 cd	2.07	0.325	1.40 bc
(ZT)	M3	0.348 ab	2.03	0.318	1.38 bc
C.V.		3.6 %	5.5 %	3.2 %	11.4 %
M1 vs. M2		-	-	-	-
M1 vs. M3		**	-	-	-
M2 vs. M3		**	+	-	-
MP vs. CP		-	**	-	**
MP vs. A		-	**	-	-
MP vs. ZT		+	*	-	-
CP vs. A		-	-	-	**
CP vs. ZT		-	-	-	**
A vs. ZT		-	*	-	-
1991	M1	0.337 bc	1.99	0.317 bc	1.62
Moldboard Plow	M2	0.342 b	1.88	0.319 bc	1.46
(MP)	M3	0.350 ab	1.93	0.316 bc	1.46
	M1	0.336 bc	1.82	0.320 bc	1.63
Chisel Plow	M2	0.323 cd	1.93	0.303 c	1.31
(CP)	M3	0.350 ab	1.94	0.333 abc	1.19
	M1	0.340 bc	1.82	0.352 a	1.17
Aerway	M2	0.313 d	1.79	0.334 ab	1.18
(A)	M3	0.362 a	1.90	0.329 abc	1.44
	M1	0.340 bc	1.75	0.353 a	0.98
Zero-Till	M2	0.316 d	1.80	0.345 ab	1.01
(ZT)	M3	0.352 ab	1.88	0.338 ab	1.26
C.V.		4.0 %	4.5 %	4.6 %	11.3 %
M1 vs. M2		**	-	-	-
M1 vs. M3		**	+	-	-
M2 vs. M3		**	-	-	-
MP vs. CP		-	-	-	-
MP vs. A		-	*	*	*
MP vs. ZT		-	**	**	**
CP vs. A		-	-	*	-
CP vs. ZT		-	+	**	**
A vs. ZT		-	-	-	-

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Note 2. +,*, ** indicates contrasts significant at the .10, .05 and .01 level

where corn was no-till planted into the oilseed radish residue. While timing of manure application had no influence on potassium availability to the corn crop, their appeared to be a nutrient cycling effect on potassium from the oilseed radish. It was a strong potassium feeder in the fall taking up approximately 125 kg K/ha in its above ground biomass. Spring analysis of the residual material indicated that very little K was present (Table 5). We would assume that most of the K was leached back into the soil. Winter-killed oilseed radish in the no-till plots would place this potassium on the soil surface while plowing it in the fall would place the material at a lower soil depth where most of the corn rooting occurs. Soil analysis performed to test this theory indicated at two of the four study sites, higher potassium levels were found in the surface horizon (0-10 cm depth) in no-till corn plots seeded into oilseed radish stubble (Table 13). Others have also noted a redistribution of potassium in the soil under no-till cover crops (Hargrove, 1986). The differences observed in ear leaf potassium nutrition between these treatments (Table 12) probably was a result of:

1) the K being more available positionally when the oilseed radish was plowed in;
2) conventionally tilled corn being better at uptaking K from the soil than no-till corn (probably due to the development of a better root system in the conventionally tilled corn).

Table 13. Effect of No-till and Moldboard Plowing on Soil Potassium Distribution in Oilseed Radish Plots

Treatments		Silt Loam		Sandy Loam	
		Moldboard Plow	Zero-Till	Moldboard Plow	Zero-Till
Spring 1990	***K (ppm)***				
Soil Depth	0- 10 cm	86	97 a	85	129
	10- 20 cm	85	71 b	54	81
	20- 30 cm	71	54 c	54	88
C.V.		13.3%	6.6%	19.8%	23.0%
Spring 1991	***K (ppm)***				
Soil Depth	0- 10 cm	156	131	122	90 a
	10- 20 cm	174	129	105	55 b
	20- 30 cm	138	95	78	55 b
C.V.		39.1%	33.0%	21.1%	14.7%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Corn Grain Yields

Yield effects between the various treatments were identified mainly at the 0 kg N/ha treatment (Table 14). Higher corn yields at the 0 kg N/ha level were generally associated with practices which increased ear leaf N. Manure treatments had greater effect on yields in 1991. Spring manure applied in 1991 provided higher corn yields than the summer manure applications. In the summer manure applications, oilseed radish improved yields over non-catch cropped plots on the silt loam site in 1991. Tillage differences were observed in both years, but were identified mainly on the heavier silt loam site. In 1990, increasing tillage intensity tended to increase corn grain

Table 14. Effect of Oilseed Radish, Tillage and Manure on Corn Grain Yield

Treatment		Silt Loam Site		Sandy Loam Site	
		0 kg N/ha	50 kg N/ha	0 kg N/ha	50 kg N/ha
1990	M1	7.98 abc	8.41	7.80	7.43
Moldboard Plow	M2	8.17 ab	8.20	7.39	8.25
(MP)	M3	8.62 a	7.71	8.10	8.19
	M1	6.91 cd	7.38	7.43	7.64
Chisel Plow	M2	7.59 abcd	7.53	7.69	7.64
(CP)	M3	7.76 abc	7.54	7.73	7.96
	M1	6.92 cd	6.87	7.80	7.68
Aerway	M2	7.38 bcd	7.32	7.79	7.78
(A)	M3	7.60 abcd	7.83	8.30	7.87
	M1	7.10 bcd	7.59	7.58	7.55
Zero-Till	M2	6.39 d	7.09	8.17	7.65
(ZT)	M3	6.90 cd	8.05	7.66	7.96
C.V.		8.5%	9.4%	6.1%	6.9%
M1 vs. M2		-	-	-	-
M1 vs. M3		+	-	-	*
M2 vs. M3		-	-	-	-
MP vs. CP		**	*	-	-
MP vs. A		-	-	-	-
MP vs. ZT		-	-	-	-
CP vs. A		*	+	-	-
CP vs. ZT		**	-	-	-
A vs. ZT		*	-	-	-
1991	M1	9.13 b	10.60	6.41	7.56
Moldboard Plow	M2	9.05 b	10.46	6.46	7.29
(MP)	M3	10.74 a	10.49	6.86	6.42
	M1	9.16 b	10.64	6.27	7.80
Chisel Plow	M2	8.80 b	10.50	6.22	7.38
(CP)	M3	10.78 a	10.79	6.98	7.36
	M1	9.10 b	10.18	6.11	7.49
Aerway	M2	7.30 c	9.98	6.28	6.81
(A)	M3	10.73 a	11.41	7.16	6.79
	M1	8.88 b	9.92	6.30	6.87
Zero-Till	M2	8.15 bc	9.49	6.39	7.20
(ZT)	M3	10.99 a	10.37	6.49	6.71
C.V.		6.8%	6.5%	10.5%	7.5%
M1 vs. M2		**	-	-	-
M1 vs. M3		**	-	*	-
M2 vs. M3		**	*	*	*
MP vs. CP		-	-	+	-
MP vs. A		*	-	+	-
MP vs. ZT		-	+	-	-
CP vs. A		+	-	-	+
CP vs. ZT		-	*	-	*
A vs. ZT		-	+	-	-

Note 1. Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

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(CP)	M3	7.76 abc	7.54	7.73	7.96
	M1	6.92 cd	6.87	7.80	7.68
Aerway	M2	7.38 bcd	7.32	7.79	7.76
(A)	M3	7.60 abcd	7.83	8.30	7.87
	M1	7.10 bcd	7.59	7.58	7.55
Zero-Till	M2	6.39 d	7.09	8.17	7.65
(ZT)	M3	6.90 cd	8.05	7.66	7.96
C.V.		8.5%	9.4%	6.1%	6.9%
M1 vs. M2		-	-	-	-
M1 vs. M3		+	-	-	*
M2 vs. M3		-	-	-	-
MP vs. CP		**	*	-	-
MP vs. A		-	-	-	-
MP vs. ZT		-	-	-	-
CP vs. A		*	+	-	-
CP vs. ZT		**	-	-	-
A vs. ZT		*	-	-	-
1991	M1	9.13 b	10.60	6.41	7.66
Moldboard Plow	M2	9.05 b	10.46	6.46	7.29
(MP)	M3	10.74 a	10.49	6.86	6.42
	M1	9.16 b	10.64	6.27	7.80
Chisel Plow	M2	8.80 b	10.50	6.22	7.38
(CP)	M3	10.78 a	10.79	6.98	7.36
	M1	9.10 b	10.18	6.11	7.49
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(A)	M3	10.73 a	11.41	7.16	6.79
	M1	8.88 b	9.92	6.30	6.87
Zero-Till	M2	8.15 bc	9.49	6.39	7.20
(ZT)	M3	10.99 a	10.37	6.49	6.71
C.V.		6.8%	6.5%	10.5%	7.5%
M1 vs. M2		**	-	-	-
M1 vs. M3		**	-	*	-
M2 vs. M3		**	*	*	*
MP vs. CP		-	-	+	-
MP vs. A		*	-	+	-
MP vs. ZT		-	+	-	-
CP vs. A		+	-	-	+
CP vs. ZT		-	*	-	*
A vs. ZT		-	+	-	-

Note 1. Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

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yield on the silt loam site. The spring of 1990 was much cooler than the spring of 1991 and conventional tillage appeared to favour increased N uptake. This probably was responsible for at least some of the yield improvement as application of nitrogen fertilizer tended to reduce yield differences. On the sandy loam site, few yield differences were observed between tillage treatments particularly in 1990 when ear leaf N levels were high in all plots. Overall the yield differences were not large between treatments considering that the no-till and Aerway plots were grown without starter fertilizer. Use of a starter fertilizer is generally recommended in minimum tillage systems.

Concluding Discussion

Efficient use is paramount in any attempt to reduce pollution potential from liquid swine manure. The study indicated that spring application of liquid manure in most instances provided the best agronomic response and that it was compatible with minimum and no-till tillage management systems. However, there is a need to take into consideration the capital investment for manure storage, spring labour requirements and weather risks of applying all the manure in the spring. Most if not all of the swine farmers in the study area are applying liquid manure after cereal harvest or in the fall. Applying liquid manure prior to seeding of an oilseed radish catch crop or possibly to an established catch crop appears to be a desirable practice from a nitrogen management standpoint. Other potential benefits of the oilseed radish are improved soil aggregate stability and weed suppression. Potentially herbicide inputs could be reduced as the oilseed radish is winter killed and would act as a mulch in low herbicide, conservation tillage systems (Smukalski et al. 1991). In addition to high herbicide use, the other problems associated with some of the no-till treatments in this study was a greater fertilizer N requirement (summer manured treatments) and lower potassium uptake (particularly in the no-till corn planted into oilseed radish residue). However, early season P uptake at the 5 leaf stage appeared to be improved under no-till planting. Overall, spring application of manure in the no-till system appeared to be the most effective means of minimizing fertilizer inputs in the no-till system.

The rainfall simulations performed to assess the runoff and soil loss from the various manure management and tillage approaches in 1989-90 (Experiment 1. Appendix), were conducted on the sandy loam site which had a very low P level (Table 9). Soil erosion was low in the fall and spring assessments (Tables 15 & 16). The site undoubtedly posed more of a risk for contributing to ground water nitrates than to surface P loss due to the very high fall nitrate levels (Table 7). Probably a more appropriate site for identifying treatment differences in runoff would have been a hog farm with a high livestock density, very high soil P levels and a clay loam soil texture. Further tests to evaluate oilseed radish's ability to reduce P loss need to be performed. If it does reduce soil P levels in the fall through plant uptake of P and then leaves little residue after winter killing, it could be a potential source of high surface ortho-P losses compared to non-cover cropped no-till systems. Perhaps direct seeding of oilseed radish into cereal residue or earlier seeding and lower seeding rates of oilseed radish have to be used to ensure high residue cover in the spring in problem P runoff areas. Using the

ground cover levels obtained in this study, the no-till managed oilseed radish residue probably would reduce ortho-P levels from current levels on the swine farms in the area as moldboard plowing and intensive corn production is standard practice. Furthermore, the combined use of cover crops and reduced tillage will lead to improved water infiltration and reduced run-off as soil tilth improves on these farms over time.

While the oilseed radish is clearly effective in reducing the nitrate pollution problem from summer manure applications it has its potential problems. In this study it was pointed out that nutrient loss could occur before the oilseed radish was sufficiently established (particularly on sandy soils) and there has been some concern that rapid decomposition of the material in the spring freeze - thaw cycle may enable nitrogen loss prior to uptake by the following corn crop. However, the other potential manure management options also have their faults. While the spring applied manure in this study provided good agronomic response it still could be problematic as this is an important period for soil compaction and surface runoff. High rates of spring applied manure are known to cause significant N loss in the fall following corn harvest because late season nitrogen use by corn is low and the manure N continues to mineralize after corn reaches physiological maturity (Estler, 1991). As well, for reasons of manure storage costs, labour use efficiency and risk of inclement weather, farmers will continue to apply manure in the fall. If this is the case, it would probably be more desirable to have the nutrients applied in late summer and tied up well into winter in the oilseed radish biomass than to practice fall "dumping" (which remains a common practice in the study area).

One of the farmers in the study area (John Van Dorp of Woodstock, Ontario) is using a split application of liquid manure in a winter wheat-corn sequence in combination with a catch crop and reduced tillage. The rationale being that it is advantageous to split the high rate application of liquid manure into two moderate applications; one in late summer in combination with the use of oilseed radish and one in spring either pre- or post-emergent in corn. The late summer manure application ensures the establishment of a productive, soil improving and weed suppressing oilseed radish catch crop while the spring manure application alleviates any potential spring nutrient problems such as P immobilization by the oilseed radish or availability of N or K under reduced tillage. In this system, the soil would not be overloaded with nutrients at any particular time. The goal with the oilseed radish is to take up nitrates as efficiently as possible from the moderate application of liquid manure so that at the onset of winter, soil nitrate levels are very low and soil moisture levels reduced. Thus when the material winter-kills, spring nitrate loss will be reduced as both the nitrogen and water content of the soil will have been lower than normal going into winter. The risk of fall leaching in the second year of the cycle could probably be further reduced after corn harvest by interseeding the corn with ryegrass when the corn is approximately 20-30 cm tall. This practice would also increase soil cover after harvest, improve soil structure and reduce late season weed pressure while having no significant effect on corn productivity (Samson et al., 1990). This system of intensive cover crop use in combination with conservation tillage and liquid manure application is further described by Estler (1991).

Experiment 1. Appendix

The Effect of Manure Application, Tillage, and Fall Cover Crops on Erosion (Performed by Ecological Services for Planning, Guelph)

Site Description

The site was located on the farm of Q. Martin, Woolwich Township, Waterloo Co. (sandy loam site, Table 2). A composite soil sample taken from the site had an organic matter content of 2.8%. The slopes at the site average 6% in the fall of 1989; one exception was the zero-till plot that received manure; this was at the extreme south part of the field and had only 3% slope. Rainfall simulation was carried out November 6-10, 1989 after fall tillage and again on May 28-31, 1990 on the same plots. Rainfall simulation was used to test the effect of four different tillage systems in conjunction with spring and summer manure applications and a fall cover crop on the amount of runoff and sediment loss.

Statistical Analysis

Statistical analyses were conducted on data using analysis of variance (ANOVA); degrees of freedom for treatment effects were partitioned into single degree of freedom orthogonal comparisons. Significance was determined at $P<0.10$.

Results and Discussion Fall 1989

Ground cover:

The amount of ground cover at the time of the rainfall simulation was dependent upon a combination of tillage and the use of oilseed radish as a cover crop (Table 15). The conventional tillage averaged 2% cover, and reduced tillage, 25%. The zero-till averaged 50% where oil radish had not been used. Ground cover consisted of wheat stubble disked in the previous August after manure application. Oilseed radish plots provided 84% cover.

Soil moisture:

There was a significant interactive effect between tillage and manure/cover crop amendments to the soil. Under conventional and reduced tillage the soil moisture averaged 21.5%. Under zero tillage, soil moisture was higher (23.5%) where there was no oilseed radish. Where oilseed radish was growing on the zero-till, soil moisture was 19.6%.

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Runoff volume:

Tillage affected the amount of runoff measured, while neither the application of manure nor the presence of oilseed radish influenced the volume of runoff (Table 15). The greatest amount of runoff occurred on the conventional and reduced tillage sites (average = 0.774 L) and the least runoff was from the zero-till (0.245 L). Reduced tillage did not decrease the volume of runoff relative to conventional tillage. All runoff volumes were low.

Soil loss:

Zero tillage reduced the amount of sediment loss (1.9 g/m^2) by 72% relative to conventional tillage (6.8 g/m^2) while reduced tillage (6.3 g/m^2) did not cause a significant reduction in soil loss relative to moldboard plowing (Table 15). The differences in soil loss were attributed to differences in runoff volumes for the treatments since the concentration of sediment in the runoff was similar for all plots, and averaged 16 g/L.

Table 15. Effect of Oilseed Radish, Manure & Tillage System on Runoff and Soil on the Sandy Loam Site in the Fall of 1989.

Treatment		Ground Cover (%)	Runoff Volume (L/m^2)	Soil Loss (g/m^2)
	M1	2.7	0.32	4.0
Moldboard Plow	M2	2.7	0.92	7.4
(MP)	M3	0	1.45	8.9
	M1	23.7	0.32	5.0
Chisel Plow	M2	30.0	1.40	11.4
(CP)	M3	22.3	0.23	2.3
	M1	84.0	0.34	0.73
Zero-Till	M2	47.7	0.18	2.5
(ZT)	M3	52.0	0.21	2.5
Probability that the difference between means of the specified contrast is zero.				
Tillage		0.000	0.164	0.138
Moldboard Plow vs Zero-till		0.000	0.063	0.071
Moldboard Plow vs Chisel		0.000	0.463	0.838
Manure		0.008	0.319	0.325
Man. & Oilradish vs Manure		0.011	0.138	0.146
Manure vs no Manure		0.621	0.541	0.325
Tillage X Manure		0.001	0.191	0.475

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(CP)	M3	22.3	0.23	2.3
	M1	64.0	0.34	0.73
Zero-Till	M2	47.7	0.18	2.5
(ZT)	M3	52.0	0.21	2.8
Probability that the difference between means of the specified contrast is zero.				
Tillage		0.000	0.164	0.138
Moldboard Plow vs Zero-till		0.000	0.063	0.071
Moldboard Plow vs Chisel		0.000	0.463	0.838
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Manure vs no Manure		0.621	0.541	0.325
Tillage X Manure		0.001	0.191	0.475

Results and Discussion Spring 1990

Ground cover and slope:

The amount of ground cover at the time of rainfall simulation was influenced by tillage and manure (Table 16). The oilseed radish crop that had provided a large amount of residue cover in November 1989 had winter killed and added little to the residue cover in May 1990. Within all tillage categories but the conventional, plots that had an oilseed radish crop the previous fall had the least amount of residue cover the following May. Grouped according to tillage, the highest percentage residue (28%) was on the zero till treatment, followed by the spring Aerway treatment at 21%, fall chisel at 15% and the fall moldboard treatment at 4.2%. The residue cover was significantly higher on the zero till treatment than the chisel and moldboard treatments. Both the Aerway and chisel treatments had significantly more residue than the moldboard treatment.

The slopes at the site averaged 3% in May 1990 which was lower than the same field plots in November 1989. It is likely that fall tillage had created exaggerated slope conditions on the micro scale which were reflected in the November slope measurements but were smoothed out over the winter and spring. The manure zero-till plot had the same average slope of 3% in November 1989 and in May 1990.

Soil moisture:

At the time of the rainfall simulations, the average soil moisture of the treatments ranged from a high of 20.3% on the Aerway + spring manure application treatment to a low of 15.6% on the zero-till treatment that had a manure application the previous summer and a fall oilseed radish crop.

Grouped by manure treatment, the average soil moisture of the treatments where manure was applied in spring (18.0%) was significantly greater than the soil moisture of the summer manure applications (16.6%) at $P<0.10$. There was no effect on soil moisture due to tillage.

Runoff volume:

The runoff volumes from the different tillage and manure treatments are shown in Table 16. Tillage had the strongest effect on the amount of runoff. Both zero till and aerwayed treatments produced significantly less runoff than the moldboard plow treatment. When runoff volumes were grouped according to tillage treatment, the greatest amount occurred on the conventional site (10.1 L) followed by the reduced tillage site (7.9 L), the aerwayed site (5.2 L) and the zero till site (4.8 L). Reduced tillage did not significantly decrease the volume of runoff relative to conventional tillage.

The spring manure treatments had significantly less runoff than the average from the summer manure applications. This was not expected, since each tillage category was subjected to the same manure incorporation technique regardless of whether spring manure was applied.

The plots that had a summer manure application and a fall oilseed radish crop had the most runoff for all but the conventional tillage system which completely incorporated the oilseed radish. The observation is difficult to explain but was probably related to the reduced soil cover which was exhibited on the winter killed oil radish treatments.

Soil loss:

The sediment losses from all of the treatments tested are shown in Table 16. The aerwayed, zero-till and reduced tillage sites generated an average of 53.5 g/m^2, 56.9 g/m^2 and 77.8 g/m^2 respectively. These amounts were significantly less than the 156.9 g/m^2 sediment loss from the conventional tillage treatment.

Table 16. Effect of Oilseed Radish, Manure & Tillage System on Runoff and Soil Loss on the Sandy Loam Site in the Spring of 1990.

Treatment		Ground Cover (%)	Runoff Volume (L/m^2)	Soil Loss (g/m^2)
	M1	7	8.6	100.7
Moldboard Plow	M2	2	11.5	245.5
(MP)	M3	4	10.3	124.4
	M1	8	9.3	85.7
Chisel Plow	M2	17	7.7	86.2
(CP)	M3	20	6.6	61.6
	M1	13	7.0	87.1
Aerway	M2	27	4.3	35.8
(A)	M3	23	4.4	37.7
	M1	25	8.3	106.4
Zero-Till	M2	25	4.5	53.6
(ZT)	M3	34	1.6	10.7
Probability that the difference between means of the specified contrast is zero.				
Tillage		0.000	0.002	0.006
Moldboard Plow vs Chisel		0.000	0.109	0.013
Moldboard Plow vs Aerway		0.000	0.001	0.002
Moldboard Plow vs Zero-till		0.000	0.001	0.002
Manure		0.015	0.109	0.179
Man. & Oilradish vs Manure		0.052	0.281	0.691
Manure vs no Manure		0.023	0.068	0.072
Tillage X Manure		0.048	0.289	0.143

The spring manure treatments had significantly less runoff than the average from the summer manure applications. This was not expected, since each tillage category was subjected to the same manure incorporation technique regardless of whether spring manure was applied.

The plots that had a summer manure application and a fall oilseed radish crop had the most runoff for all but the conventional tillage system which completely incorporated the oilseed radish. The observation is difficult to explain but was probably related to the reduced soil cover which was exhibited on the winter killed oil radish treatments.

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	M1	8	9.3	85.7
Chisel Plow	M2	17	7.7	88.2
(CP)	M3	20	6.6	61.6
	M1	13	7.0	87.1
Aerway	M2	27	4.3	35.8
(A)	M3	23	4.4	37.7
	M1	25	8.3	106.4
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Man. & Oilradish vs Manure		0.052	0.281	0.691
Manure vs no Manure		0.023	0.068	0.072
Tillage X Manure		0.048	0.289	0.143

Experiment 2

Effect of Manure and Rye Cover Crop on No-Till Soybean Production

Introduction

The objective of this trial was to evaluate the effect of manure and a rye cover crop on no-till soybean production. A late summer manure application prior to seeding of a rye cover crop may be an effective way of improving soil structure while reducing the pollution potential of a manure application. Rye cover crops can improve soil aggregate stability (Benoit et al., 1962) and can be used as a weed suppressing mulch to reduce herbicide inputs in no-till soybean production. This trial is a continuation of a two year study in which different management practices were evaluated in a soybean production system called "no-till mow-kill". In this system, soybeans are directly drilled into standing rye at the time of anthesis in late May. The rye is subsequently mowed to form a weed suppressing mulch. On some farms, the soybeans have appeared chlorotic when no-till planted into a rye cover crop compared to no-till treatments without a rye cover crop. The hypothesis was that this chlorotic condition (apparent N deficiency) was due to large quantities of nutrients being taken up by the rye during its rapid growth early in the season. Manure was used in an attempt to alleviate the apparent fertility problems being experienced. High no-till soybean yields were obtained in a previous trial in which the rye had received liquid manure prior to establishment (Samson et al.,1990).

A satellite trial was also performed in 1989-90 to determine the effects of nitrogen and potassium fertilizer on improving soybean plant development. The fertilizers were applied to the rye, prior to its rapid spring development, approximately 1 month before soybean seeding. As well, subplots were established within the main experiment in 1991 to determine whether soybean yields were affected by weed growth in mow-killed rye.

Materials and Methods

A summary of the materials and methods used in the experiment is found in Table 17. The experiment was modified in 1990-91 in an attempt to further understand the nutrient deficiencies that were occurring. Soil nutrient status and early season plant development were monitored more closely. The manure application rate was increased to 50 t/ha to increase the quantity of nutrients provided by the manure and the manure source was changed to a solid dairy manure. This manure source also had a higher nutrient analysis than the solid beef manure used in 1989-90 (Table 19).

Table 17. Summary of Experimental Methods and Design

Main Plot Treatments	
1. Rye seeded in late August	
2. Rye seeded in late September	
3. Manure + rye seeding in late August	
4. Manure + rye seeding in late September	
5. Manure	
6. Control	
Sub Plots (1991 only)	
a) post emergent hand weeding	
b) no hand weeding	
Statistical Design	
Layout	Randomized complete block design with split plot
Number of replications	3
Main plot size	3.75 m x 16 m
Sub plot size	3.75 m x 8 m
General Information	
Cooperator	Harry Wilhelm, Tavistock, Ontario
Soil type	Silt loam
Rye seeding (broadcast with hand held cyclone seeder)	130 kg/ha common rye (tobacco belt)
Rye seeding dates	Aug. 31 & Sept. 30/89, Sept. 1 & Oct. 15/90
Glyphosate application rate and dates (bare plots)	1.25 l/ha, May 20/89 & May 15/90
Manure types and rates	Solid beef & swine manure @ 30t/ha in 1989-90 Solid dairy manure @ 50 t/ha in 1990-91
Manure application (weighed in buckets, broadcast and disked in)	Aug. 31/ 89 & Sept. 1/90 (treatment 3) Sept. 30/89 & Oct. 1/90 (treatments 4 & 5)
Fall tillage (2 diskings prior to rye seeding)	Aug. 31 & Sept. 30/89, Sept. 1 & Oct. 15/90)
Ground cover measurements (rope knot technique)	Oct. 23/89, May 2 & June 19/90 Nov. 5/90, May 2 & June 3/91
Rye biomass (3 x 1 m^2 quadrats)	May 30/ 90 & June 1/91
Soybean seeding: (Pioneer 0877: 100 kg/ha)	38 cm rows, May 30/89 19 cm rows, June 3/91
Rye mowing date	May 31/90, June 3/91
Rye regrowth measurement	June 19/90
Post emergent weed control	Basagran @ 2.6 l/ha on July 6/90 + hand weeding (non-rye plots), no weeding on rye plots in 1990
Whole plant tissue analysis	10 plants per plot , July 2/91
Leaf tissue analysis	20 top trifoliate leaves at flowering, July 26/90 & July 21/91
Soil analysis	10 cores per plot , 0-15 cm depth, Aug. 17/90, Aug. 15/91
Soybean harvest	2 x 5 m rows, Oct. 17/90; 9 x 5m rows, Oct. 15/91
Weed harvest (4 x 1 m^2 quadrats)	Sept. 10/91

Table 18. Summary of Experimental Methods and Design: Satellite Study

Main Plot Treatments	
1. Kustro Rye	
2. MSU 15 Rye	
Sub Plot Treatments	
1. 50 kg N/ha (applied as urea)	
2. 100 kg K/ha (applied as muriate of potash)	
3. 50 kg N/ha + 100 kg K/ha	
4. Control (no fertilizer)	
Statistical Design	
Layout	Randomized complete block design with split plot
Number of replications	3
Main plot size	3.75 m x 16 m
Sub plot size	3.75 m x 4 m
General Information	
Cooperator	Harry Wilhelm, Tavistock, Ontario
Soil type	Silt loam
Rye seeding	130 kg/ha, Sept. 30/89
Fertilizer Applications	May 2/90
Soybean seeding: (Pioneer 0877: 100 kg/ha)	38 cm rows, May 30/89
Rye mowing date	May 31/90
Soybean harvest	2x 3 m rows, Oct. 17/90

Table 19. Analysis of Solid Manure Applied in 1989 and 1990

Manure Type	Dry Matter %	Nutrient Concentration % N	% P	% K
1989 Beef & Swine	29.4	0.69	0.21	0.92
1990 Dairy	26.4	0.74	0.21	1.39
Quantity Applied		**Total Nutrients Applied (kg/ha) N**	**P**	**K**
1989 Beef & Swine : 30 t/ha		*207	63	276
1990 Dairy: : 50 t/ha		*370	105	695

** rough estimate of nitrogen available from a fall manure application would be approximately 25% of total N applied (OMAF, 1992)*

Table 18. Summary of Experimental Methods and Design: Satellite Study

Main Plot Treatments	
1. Kustro Rye	
2. MSU 15 Rye	
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1. 50 kg N/ha (applied as urea)	
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3. 50 kg N/ha + 100 kg K/ha	
4. Control (no fertilizer)	
Statistical Design	
Layout	Randomized complete block design with split plot
Number of replications	3
Main plot size	3.75 m x 16 m
Sub plot size	3.75 m x 4 m
General Information	
Cooperator	Harry Wilhelm, Tavistock, Ontario
Soil type	Silt loam
Rye seeding	130 kg/ha, Sept. 30/89
Fertilizer Applications	May 2/90
Soybean seeding: (Pioneer 0877: 100 kg/ha)	38 cm rows, May 30/89
Rye mowing date	May 31/90
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1990 Dairy: : 50 t/ha		*370	105	695

** rough estimate of nitrogen available from a fall manure application would be approximately 25% of total N applied (OMAF, 1992)*

Results and Discussion

Ground Cover

In both 1989 and 1990, the best fall ground cover was obtained where manure was applied to an early rye seeding (Table 20) . The manure itself contained a considerable amount of straw and this increased residue cover in both years. In both years, the solid manure treatments which were incorporated using two fall diskings provided superior fall ground cover than the late planted rye treatment. By early May, all rye treatments provided high ground cover measurements except for the late planted rye in 1990-91 which was slow to start spring growth. This was likely due to its very late establishment date (October 15) in the wet fall of 1990. The use of solid manure with the late planted rye appeared to improve winter survival and resulted in better spring cover. Following no-till soybean planting in late May / early June, all rye cover crop plots maintained a high residue cover (>70%) with the early seeded rye treatments approaching 100%.

Because the plots were too small to perform a rainfall simulation, another site was used to determine the potential for soil erosion in no-till soybean systems. The rainfall simulation indicated that there was a 90% reduction in soil erosion and approximately a 60% reduction in the volume of runoff where the rye cover crop was left as a surface no-till mulch compared to the bare control treatment (Table 21). At the time of the rainfall simulation, the ground cover present in the no-till plots with a rye cover crop was 95%. This was similar to the early seeded rye plots in the manure study. However, the control plot provided 57% cover while that of the control plot in the manure study was only 12%.

Table 20. Effect of Winter Rye and Manure on Ground Cover

Treatment	1989-90 Ground Cover (%)			1990-91 Ground Cover (%)		
	Oct. 23, 1989	May 2, 1990	June 19, 1990	Nov. 5, 1990	May 2, 1991	June 3, 1991
Rye seeded early	76 b	82 b	93 a	78 b	84 a	99 a
Rye seeded late	13 d	43 c	75 ab	18 d	21 c	72 b
Manure + early rye	91 a	94 a	96 a	90 a	93 a	100 a
Manure + late rye	42 c	73 b	93 a	33 c	51 b	81 b
Manure	35 c	51 c	51 b	32 c	32 c	17 c
Control	5 d	14 d	11 c	4 e	16 c	12 c
C.V.	11.3%	8.6%	20.1 %	7.5 %	19.3 %	19.3 %

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Results and Discussion

Ground Cover

In both 1989 and 1990, the best fall ground cover was obtained where manure was applied to an early rye seeding (Table 20) . The manure itself contained a considerable amount of straw and this increased residue cover in both years. In both years, the solid manure treatments which were incorporated using two fall diskings provided superior fall ground cover than the late planted rye treatment. By early May, all rye treatments provided high ground cover measurements except for the late planted rye in 1990-91 which was slow to start spring growth. This was likely due to its very late establishment date (October 15) in the wet fall of 1990. The use of solid manure with the late planted rye appeared to improve winter survival and resulted in better spring cover. Following no-till soybean planting in late May / early June, all rye cover crop plots maintained a high residue cover (>70%) with the early seeded rye treatments approaching 100%.

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Table 20. Effect of Winter Rye and Manure on Ground Cover

Treatment	1989-90 Ground Cover (%)			1990-91 Ground Cover (%)		
	Oct. 23, 1989	May 2, 1990	June 19, 1990	Nov. 5, 1990	May 2, 1991	June 3, 1991
Rye seeded early	78 b	82 b	93 a	78 b	84 a	96 a
Rye seeded late	13 d	43 c	75 ab	18 d	21 c	72 b
Manure + early rye	91 a	94 a	96 a	90 a	93 a	100 a
Manure + late rye	42 c	73 b	93 a	33 c	51 b	81 b
Manure	35 c	51 c	51 b	32 c	32 c	17 c
Control	5 d	14 d	11 c	4 e	16 c	12 c
C.V.	11.3%	8.6%	20.1 %	7.5 %	19.3 %	19.3 %

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Table 21. Effect of Rye Cover Crop on Soil Erosion and Runoff in No-Till Soybean Production (May 30-31, 1991, farm of D. Smith, Thamesville, Ontario, performed by Ecological Services for Planning, Guelph, Ont.)

Treatment	Slope (%)	Ground Cover (%)	Soil Moisture (%)	Runoff (L/m2)	Soil Loss (g/m2)
Rye Cover Crop	2.9 a	95 a	17.5 a	6.0 b	0.2 b
Control (no cover crop)	2.5 a	57 b	18.3 a	14.2 a	2.1 a

Note 1. 10 minute rainfall at 154.8 mm/hr intensity
Note 2. Means within the same column followed by the same letter are not significantly different at the 0.10 probability level.

Effect of Manure and Rye Cover Crop on Nutrient Dynamics in No-Till Soybean Production

In both years the highest rye biomass was obtained when the rye was seeded early and manure was used as a nutrient source (Table 22). However, time of planting had a much greater effect on rye biomass production and composition than did application of manure. In the fall of 1990, wet weather delayed rye seeding until October 15 and biomass production in the spring of 1991 was relatively low. The early planted rye contained a lower P level than the late planted rye in both years. Compared to the late planted rye, it was more mature at the time of no-till planting and rye mowing in late May / early June. The combination of a higher biomass yield, lower P content and more advanced maturity obtained in the early rye seeding may be important in reducing the surface transport of total P and soluble P from the field. Some studies have suggested that significant surface loss of bioavailable P can occur from the cover crop itself (reviewed by Sharpley and Smith, 1991). If the rye advances to the anthesis state before its destruction, surface transport of both total P and bioavailable P would be minimized. When managed as a no-till cover crop killed at heading or anthesis, rye has a C:N ratio of at least 40:1 and is slow to decompose (Somda et al., 1991). A high yielding rye cover crop killed at heading would lead likely to less bioavailable P loss than a cover crop which is killed at an early stage. Early killing would provide lower residue cover, the %P in the rye residue would be higher, and the immature plant material would breakdown more easily. One study in which a rye cover crop was killed at a very immature state, found that both total P and bioavailable P were increased compared to the bare no-till treatment (Staver and Brinsfield, 1991). If allowed to reach anthesis before killing it, rye has many characteristics which make it an ideal cover crop for reducing P loss:

1) high biomass yield which provides nearly 100 % soil cover when left as a surface no-till mulch;
2) slow decomposition rate which maintains high soil cover and reduces P leaching;
3) low % tissue P compared to other cover crops when killed at an advanced state of maturity (Calegari, 1991)

Table 22. Effect of Manure and Time of Seeding on Rye Biomass Production and Nutrient Content at Rye Heading

Treatment	Weight (kg/ha)	Nutrient Content			Nutrient Uptake		
		%N	% P	%K	N	P	K
1990						(kg/ha)	
Rye seeded early	3467 ab	1.22 b	0.28 b	1.93 b	43	9.6	71
Rye seeded late	2061 b	1.55 a	0.33 a	2.34 a	32	6.8	49
Manure + early rye	5188 a	1.19 b	0.31ab	1.96 b	59	15.5	100
Manure + late rye	2939 b	1.56 a	0.32 a	2.42 a	46	9.4	71
C.V.	29.9%	6.8%	6.1%	3.4%	24.6%	25.9%	25.9%
1991						(kg/ha)	
Rye seeded early	4610 a	0.83 b	0.29 b	1.99 b	38 a	13 a	91 a
Rye seeded late	1629 b	1.62 a	0.37 a	2.40 a	26 b	6 b	39 b
Manure + early rye	5594 a	0.83 b	0.29 b	2.06 b	46 a	16 a	115 a
Manure + late rye	1787 b	1.50 a	0.38 a	2.57 a	26 b	7 b	46 b
C.V.	16.4%	8.6%	8.7%	5.3%	15.6%	19.4%	17.3%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Effect of Rye and Manure on Soil Fertility and Soybean Nutrition

As previously mentioned, one of the concerns of using a rye cover crop in no-till soybean production is its effect on soybean nutrition. A gross nutrient balance and sequential sampling of the soybeans was used to assess the effects of the rye cover crop and manure on soybean growth. The rye cover crop by itself had no significant effects on P and K availability in the soil when measured midsummer in both years (Table 23). Contrasts revealed that manure significantly increased soil potassium in both years and phosphorus in 1990. The 1990-91 site had higher P and K levels than the 1989-90 site. As well, both the rate and concentration of the manure were increased from the previous year.

Table 23. Effect of Manure and Rye Cover Crop on Soil Phosphorus and Potassium

Treatment	1990		1991	
	P ppm	K ppm	P ppm	K ppm
Rye seeded early	12	52	30	98 bc
Rye seeded late	11	51	28	82 c
Manure + early rye	16	67	37	183 a
Manure + late rye	14	60	29	140 ab
Manure	15	68	28	125 abc
Control	13	51	25	71 c
C.V.	15.2%	14.4%	44.8%	26.6 %
Early vs. late rye	-	-	-	-
Manure vs. no manure	*	**	-	**
Rye vs. no rye	-	-	-	+

Note 1: Means within the same column followed by the same letter are not significantly different at the .05 level according to Duncan's multiple range test.
Note 2: **,*,+ indicates significance at the .01, .05, and .10 level respectively

Perhaps the rye's most significant effect was on surface soil nitrates (Table 24). In 1991, early season nitrate levels were significantly reduced under the rye cover crop treatments, particularly at the 0-20 cm sampling depth. Soil nitrates at this depth under the rye cover crop treatments were very low, approximately 2.0 ppm. This reduction in soil nitrates under a no-till rye cover is similar to results obtained by Brinsfield and Staver (1991) and Hoyt and Mikkelsen (1991). Research has indicated that rye can play an important role in reducing nitrate loss over winter (Muller et al., 1989; Staver et al., 1991). The early planted rye would be much more effective in this role than the late planted rye. The early planted rye was well established going into winter and provided higher total N uptake during the spring growth period.

Table 24. Effect of Rye Cover Crop and Manure on Soil N at Soybean Planting in 1991

Treatment	% Moisture (0-40 cm soil depth)	NH_4-N (ppm) (0-40 cm soil depth)	NO_3-N (ppm) (0-20 cm soil depth)	NO_3-N (ppm) (20-40 cm soil depth)
Rye seeded early	22.7	1.45	2.5 b	2.0 b
Rye seeded late	22.3	1.60	2.6 b	2.1 b
Manure + early rye	23.0	1.39	2.8 b	2.0 b
Manure + late rye	23.5	1.69	3.4 b	2.4 b
Manure	24.3	1.48	7.9 a	4.9 a
Control	23.1	1.66	8.1 a	4.8 a
C.V.	4.6%	43.2%	21.9%	20.2%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Satellite Experiment

At the outset of the experiment it was hypothesized that rye was extracting large quantities of nutrients from the soil in the month of May and that this was a factor in the chlorotic condition observed in no-till soybeans on several sites in the past (including the farm in which the study was conducted). As a result, it was anticipated that a nutrient rich manure source would compensate for the nutrient tie up by the rye cover crop and improve soybean growth. The manure application in 1989-90 improved soybean leaf tissue K content at soybean flowering in 1989-90 but had no affect on N or P tissue levels (Table 26). A satellite study testing different N and K fertilizer combinations (on rye in early May) indicated that K was not the limiting nutrient as application of 100 kg/ha of K did not increase the soybean yield compared to the control. However, early May application of nitrogen fertilizer to the plots with or without K fertilizer increased the rye cover crop growth (observed visually). Soybean yields were significantly lower on the plots which had increased rye growth as a result of the application of 50 kg N/ha in early May.

Table 22. Effect of Manure and Time of Seeding on Rye Biomass Production and Nutrient Content at Rye Heading

Treatment	Weight (kg/ha)	Nutrient Content %N	%P	%K	Nutrient Uptake N	P	K
1990						(kg/ha)	
Rye seeded early	3467 ab	1.22 b	0.28 b	1.93 b	43	9.6	71
Rye seeded late	2061 b	1.55 a	0.33 a	2.34 a	32	6.8	49
Manure + early rye	5188 a	1.19 b	0.31ab	1.96 b	59	15.5	100
Manure + late rye	2939 b	1.56 a	0.32 a	2.42 a	46	9.4	71
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1991						(kg/ha)	
Rye seeded early	4610 a	0.83 b	0.29 b	1.99 b	38 a	13 a	91 a
Rye seeded late	1629 b	1.62 a	0.37 a	2.40 a	26 b	6 b	39 b
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Manure + late rye	1787 b	1.50 a	0.38 a	2.57 a	26 b	7 b	46 b
C.V.	16.4%	8.6%	8.7%	5.3%	15.6%	19.4%	17.3%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Effect of Rye and Manure on Soil Fertility and Soybean Nutrition

As previously mentioned, one of the concerns of using a rye cover crop in no-till soybean production is its effect on soybean nutrition. A gross nutrient balance and sequential sampling of the soybeans was used to assess the effects of the rye cover crop and manure on soybean growth. The rye cover crop by itself had no significant effects on P and K availability in the soil when measured midsummer in both years (Table 23). Contrasts revealed that manure significantly increased soil potassium in both years and phosphorus in 1990. The 1990-91 site had higher P and K levels than the 1989-90 site. As well, both the rate and concentration of the manure were increased from the previous year.

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C.V.	15.2%	14.4%	44.8%	26.6 %
Early vs. late rye	-	-	-	-
Manure vs. no manure	*	**	-	**
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Note 1: Means within the same column followed by the same letter are not significantly different at the .05 level according to Duncan's multiple range test.

Note 2: **,*,+ indicates significance at the .01, .05, and .10 level respectively

Perhaps the rye's most significant effect was on surface soil nitrates (Table 24). In 1991, early season nitrate levels were significantly reduced under the rye cover crop treatments, particularly at the 0-20 cm sampling depth. Soil nitrates at this depth under the rye cover crop treatments were very low, approximately 2.0 ppm. This reduction in soil nitrates under a no-till rye cover is similar to results obtained by Brinsfield and Staver (1991) and Hoyt and Mikkelsen (1991). Research has indicated that rye can play an important role in reducing nitrate loss over winter (Muller et al., 1989; Staver et al., 1991). The early planted rye would be much more effective in this role than the late planted rye. The early planted rye was well established going into winter and provided higher total N uptake during the spring growth period.

Table 24. Effect of Rye Cover Crop and Manure on Soil N at Soybean Planting in 1991

Treatment	% Moisture (0-40 cm soil depth)	NH_4-N (ppm) (0-40 cm soil depth)	NO_3-N (ppm) (0-20 cm soil depth)	NO_3-N (ppm) (20-40 cm soil depth)
Rye seeded early	22.7	1.45	2.5 b	2.0 b
Rye seeded late	22.3	1.66	2.6 b	2.1 b
Manure + early rye	23.0	1.39	2.8 b	2.0 b
Manure + late rye	23.5	1.69	3.4 b	2.4 b
Manure	24.3	1.48	7.9 a	4.9 a
Control	23.1	1.66	8.1 a	4.9 a
C.V.	4.6%	43.2%	21.9%	20.2%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Satellite Experiment

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Table 25. Effect of Fertilizer Treatment on No-Till Soybean Planted into Winter Rye in 1990

Fertility Treatment (sub-plot)	Yield (kg/ha at 14% moisture)
1. 50 kg N/ha	1277 b
2. 100 kg K/ ha	2197 a
3. 50 kg N + 100 kg K/ha	1253 b
4. No fertilizer	1995 a
Variety Effect (main plot)	
1. Kustro	1875 a
2. MSU 15	1485 b

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Soybean Nutrition

In 1990-91, the present study and a separate SWEEP-TED study exploring the effect of nutrient immobilization by rye on weed suppression (Samson et al, 1992), further attempted to identify what was causing the chlorotic condition of the soybeans and delayed early season development where a rye cover crop was present. It was speculated that soybean growth was being affected by both large quantities of N and P being taken up early in the season by the rye cover crop as well as microbial immobilization of N and P as the high carbon mulch slowly decomposed at the soil surface. In 1990 the rye cover crop contained as much as 59 kg N/ha and 16 kg P/ha which had accumulated during its rapid spring growth. As well, several studies have indicated that decomposing surface residues and roots cause microbial immobilization of nutrients (primarily N and P) if the residue possesses a high C:N ratio and low N content. Breland (1990) considered that any species with a nitrogen content between 1.2-1.8% N causes N immobilization in the form of microbial biomass. The rye in the present study had a nitrogen content of approximately 1-1.5% and although the C/N ratio was not measured, it was likely in the order of 40:1 based on its stage of maturity at time of mowing.

In 1991, a more complete early season assessment of soil nutrients and nutrient uptake by the young soybean plants was undertaken. From the soil nitrate data in Table 24 it can be observed that at the time of soybean planting the rye had resulted in low nitrate levels in the soil. The weight of individual soybean plants harvested 30 days after planting was also significantly reduced where rye cover crops were present. Contrasts indicated that the nitrogen content of the soybean plants was reduced where the rye was present as well as the % P in the top trifoliate leaf at flowering (sampled 55 days after planting). The rye cover crop also appeared to be influencing N content of the soybean at the time of top trifoliate sampling. In 1991, the lowest soybean nitrogen content seemed to be associated with the early planted rye treatments and rye treatments which had received solid manure the previous fall. In both years, the plots which had received manure or had a rye cover crop seeded early also tended to have the highest K tissue levels when sampled at flowering. The K tissue levels from the top

trifoliate at flowering in 1991 were well above 2.5%, the upper limit of what is considered a normal concentration in soybeans (OMAF, 1990).

Table 26. Effect of Manure and Rye Cover Crop on Soybean Tissue Content and Plant Weight

Treatments	30 Days After Planting (whole plant)				55 Days After Planting (top trifoliate)		
	N %	P %	K %	Dry Wt. (g)	N %	P %	K %
1990							
Rye seeded early	-	-	-	-	5.58	0.52	2.14 b
Rye seeded late	-	-	-	-	5.55	0.51	1.95 c
Manure + early rye	-	-	-	-	5.43	0.52	2.35 a
Manure + late rye	-	-	-	-	5.55	0.52	2.26 a
Manure	-	-	-	-	5.68	0.56	2.10 b
Control	-	-	-	-	5.77	0.53	1.83 c
C.V.	-	-	-	-	3.2 %	3.4%	3.1 %
Contrasts							
early vs. late rye					-	-	**
manure vs. no manure					-	-	**
rye vs. no rye					+	*	**
1991							
Rye seeded early	3.43	0.39	2.34 bc	0.76 c	5.26 bc	0.48	3.20 a
Rye seeded late	3.55	0.40	2.47 bc	0.83 c	5.81 a	0.48	2.59 c
Manure + early rye	3.18	0.36	3.17 a	0.66 c	5.05 c	0.46	3.06 ab
Manure + late rye	3.47	0.37	3.17 a	0.83 c	5.23 bc	0.48	3.14 a
Manure	3.85	0.35	2.95 ab	1.56 a	5.38 abc	0.50	2.84 abc
Control	3.83	0.37	2.22 c	1.27 b	5.58 ab	0.49	2.67 bc
C.V.	8.5%	4.7%	12.3%	13.2%	4.2 %	3.4%	7.4 %
Contrasts							
early vs. late rye	-	-	.	-	*	-	+
manure vs. no manure	-	**	**	-	*	-	+
rye vs. no rye	*	+	-	**	-	*	*

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Note 2: +, *, ** indicates significance at the 10%, 5% and 1 % level.

Soybean Plant Stand and Yield.

In 1990, contrasts indicated that the rye may have had some influence on reducing soybean yield and that the late planted rye had poorer soybean yields than the early planted rye plots (Table 27). Visually, the soybeans were shorter and a paler green colour in all four rye treatments compared to the manure and control treatment with no rye cover crop.

In 1991, plant densities appeared to be reduced under the rye cover crop and subsequent counts indicated that the use of both manure and rye reduced plant stand (Table 28). The lowest plant stand was obtained on the plot which received manure and had an early rye seeding in the previous fall. It is well known that rye can deplete soil moisture rapidly once it reaches the heading stage and that timeliness of seeding can be

trifoliate at flowering in 1991 were well above 2.5%, the upper limit of what is considered a normal concentration in soybeans (OMAF, 1990).

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1990							
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Rye seeded late	-	-	-	-	5.55	0.51	1.95 c
Manure + early rye	-	-	-	-	5.43	0.52	2.35 a
Manure + late rye	-	-	-	-	5.55	0.52	2.26 a
Manure	-	-	-	-	5.68	0.56	2.10 b
Control	-	-	-	-	5.77	0.53	1.83 c
C.V.	-	-	-	-	3.2 %	3.4%	3.1 %
Contrasts							
early vs. late rye					-	-	**
manure vs. no manure					-	-	**
rye vs. no rye					+	*	**
1991							
Rye seeded early	3.43	0.39	2.34 bc	0.76 c	5.26 bc	0.48	3.20 a
Rye seeded late	3.55	0.40	2.47 bc	0.83 c	5.81 a	0.48	2.59 c
Manure + early rye	3.18	0.36	3.17 a	0.66 c	5.05 c	0.46	3.06 ab
Manure + late rye	3.47	0.37	3.17 a	0.83 c	5.23 bc	0.48	3.14 a
Manure	3.85	0.35	2.95 ab	1.56 a	5.38 abc	0.50	2.84 abc
Control	3.83	0.37	2.22 c	1.27 b	5.58 ab	0.49	2.67 bc
C.V.	8.5%	4.7%	12.3%	13.2%	4.2 %	3.4%	7.4 %
Contrasts							
early vs. late rye	-	-	-	-	*	-	+
manure vs. no manure	-	**	**	-	*	-	+
rye vs. no rye	*	+	-	**	-	*	*

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Table 27. Effect of Rye Cover Crop and Manure on No-Till Soybean Yield in 1990

Main Plot Treatments	Soybean Yield (kg/ha at 14% moisture)
Rye seeded early	3554
Rye seeded late	2905
Manure + rye seeded early	3675
Manure + rye seeded late	3184
Manure	3993
Control	3715
C.V.	14.1%
Rye vs. no rye	+
Rye early vs. rye late	+
Manure vs. no manure	-

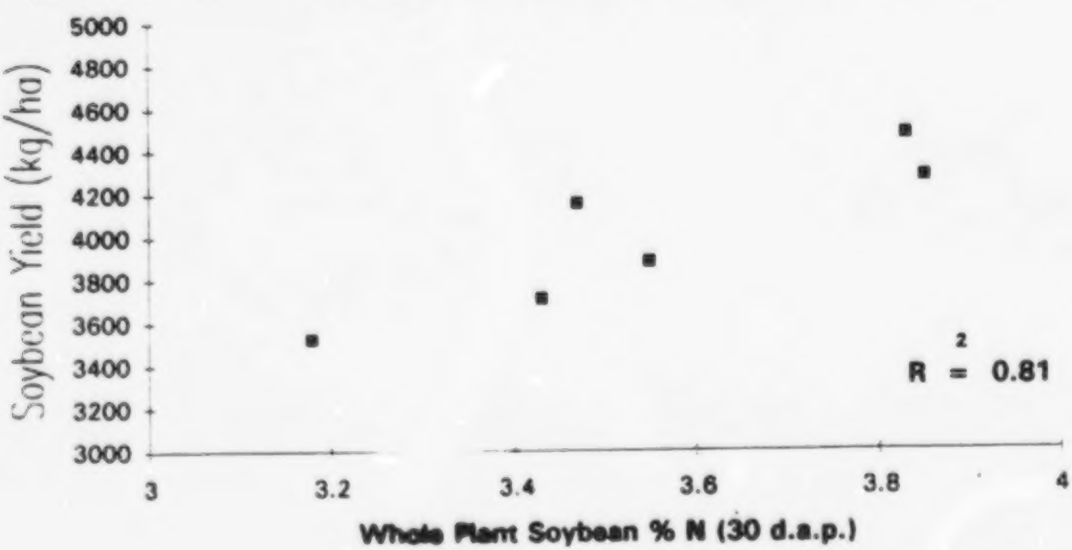
Note : + indicates significance at the 10% level.

Table 28. Effect of Manure and Rye Cover Crop on Soybean Plant Density and No-Till Soybean Yield in 1991

Treatment	Population (plants/ha)	Soybean Yield (kg/ha at 14% moisture)		
		Weeded	Unweeded	Average
Rye seeded early	345,777 b	3710	3505	3607
Rye seeded late	398,122 ab	3882	3100	3491
Manure + early rye	281,906 c	3523	3382	3452
Manure + late rye	377,508 ab	4156	3380	3768
Manure	390,807 ab	4278	4017	4147
Control	410,639 a	4474	3763	4118
C.V.	6.4%			
The L.S.D. for comparing yield differences within and between the weeded and unweeded treatments is 457 kg.				

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Figure 1. Correlation Between Soybean Yield and Whole Plant % N in 1991



critical. In 1991, the timeliness of plot operations proved difficult as heavy rains delayed soybean seeding. Delaying planting until the bare plots were capable of supporting field equipment appeared to allow excessive moisture loss from the rye plots which probably contributed to the lower plant stand on rye plots having the highest rye biomass.

In 1991, very little rye regrowth occurred on any of the plots and hand weeding was used for weed control. Rye plots appeared to inhibit soybean growth and yield. A correlation co-efficient ($R^2 = .81$) indicated that the plots with the lowest whole plant N concentration (%) at 30 days after planting also had the lowest soybean yield (Fig. 1). Both of the late seeded rye plots responded to hand weeding while there was no significant effect of hand weeding on soybean yield where the early seeded rye was mowed and left as a surface mulch (Table 28).

Weed Control

The weed pressure was generally low in the trial and a large variety of weeds were present. The low weed pressure and high experimental error caused few differences to be observed, particularly in the case of perennial weeds (Table 29). The main effects appeared to be that the early seeded rye was more effective than the late seeded rye in reducing both the number and biomass of annual weeds and total weeds (annual + perennial). The higher weed pressure in the late seeded rye plots resulted in greater differences in soybean yields between weeded and unweeded plots. Bare plots had low perennial weed pressure because a contact herbicide had been sprayed on the plots prior to soybean planting. The plot which had the greatest total weed biomass was the manure + late seeded rye plot. This plot had a heavier rye mulch than the late seeded rye plot without manure indicating that the manure stimulated weed growth.

Table 29. Effect of Manure and Rye Cover Crop On Weed Density and Biomass in No-Till Soybeans in 1991

Treatments	Annual Weeds		Perennial Weeds		Total Weeds	
	#/ m^2	kg/ha	#/m^2	kg/ha	# /m^2	kg/ha
Rye seeded early	9.4 b	115	12.1	129	18.4 b	272 b
Rye seeded late	24.4 a	406	12.0	158	36.4 ab	565 b
Manure + early rye	10.1 b	195	5.4	180	11.6 b	375 b
Manure + late rye	26.1 a	526	28.4	695	54.5 a	1221 a
Manure	8.3 b	430	1.8	4	10.1 b	434 b
Control	10.1 b	540	0.3	0	10.4 b	540 b
C.V.	34.9 %	51.4 %	149.6%	134.6%	58.9%	51.6 %
Contrasts						
early vs. late rye	**	*	-	-	**	*
manure vs. no man.	-		-	-	-	-
rye vs. no rye	*	*	-	+	*	-

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C.V.	14.1%
Rye vs. no rye	+
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		Weeded	Unweeded	Average
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Manure + early rye	281,906 c	3523	3382	3452
Manure + late rye	377,506 ab	[illegible]	3380	3768
Manure	390,807 ab	4278	4017	4147
Control	410,639 a	4474	3763	4118
C.V.	6.4%			
The L.S.D. for comparing yield differences within and between the weeded and unweeded treatments is 457 kg.				

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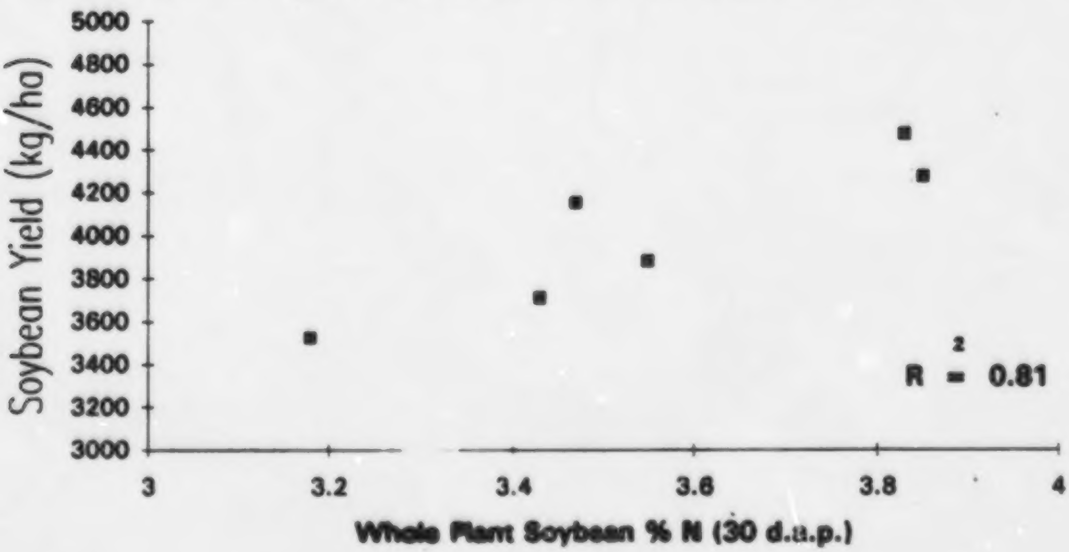

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Treatments	Annual Weeds		Perennial Weeds		Total Weeds	
	#/ m^2	kg/ha	#/m^2	kg/ha	# /m^2	kg/ha
Rye seeded early	9.4 b	115	12.1	129	18.4 b	272 b
Rye seeded late	24.4 a	406	12.0	158	36.4 ab	565 b
Manure + early rye	10.1 b	195	5.4	180	11.6 b	375 b
Manure + late rye	26.1 a	526	28.4	695	54.5 a	1221 a
Manure	8.3 b	430	1.8	4	10.1 b	434 b
Control	10.1 b	540	0.3	0	10.4 b	540 b
C.V.	34.9 %	51 4 %	149.6%	134.6%	58.9%	51.6 %
Contrasts						
early vs. late rye	**	*	-	-	**	*
manure vs. no man.	-		-	-	-	-
rye vs. no rye	*	*	-	+	*	-

Note 1: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Note 2: +, *, ** indicates significance at the 10 %, 5 % and 1 % level.

Concluding Discussion

The benefits of using a rye mulch in no-till soybean production are many including improved soil structure, reduced herbicide inputs, minimized surface transport of nutrients, minimized nitrate leaching and moisture conservation. From a manure management and pollution standpoint, an August application of manure followed by the seeding of a rye cover crop appears to be a promising system. Manure incorporation is made during a low runoff period when the soils are generally dry. The rye cover crop establishes rapidly after seeding and along with the no-till soybean crop, provides over 90% ground cover for a period of approximately 1 year after the rye is seeded. However, it is yet to be determined what is causing reduced nutrient availability in the soybeans no-tilled into the winter rye.

The second year of the experiment indicated that rye depletes soil N at the time of planting. This may explain delayed growth of the soybeans. However, if soybeans fix their own N this does not explain the lower N level in the soybeans planted into rye plots when measured at flowering in 1991 (Table 26). The two factors that are speculated to be causing the extended delay in soybean development in the rye plots are: 1) microbial immobilization of nutrients because of the breakdown of carbon rich mulch by the microbial biomass and 2) cooler soil temperatures under the rye mulch which reduces nitrogen fixation.

In a previous experiment in which liquid manure was applied prior to rye seeding, an outstanding rye cover was obtained, effective weed control was provided, minimal rye regrowth occurred, and a high soybean yield resulted (Samson et al., 1990). Perhaps a more positive response from manure on soybean growth would have been obtained if liquid manure had been used instead of solid manure. The C:N ratios of the manure (containing large quantities of straw) and the rye cover crop killed at anthesis may have been too high. Liquid manure has a low C:N ratio and may be ideally suited for use with a high C:N ratio plant such as rye. In cash crop systems, where no livestock manure is available, it may be interesting to evaluate the effect of a liquid starter fertilizer on improving early season soybean growth and final yield.

Experiment 3

Effect of Tillage System, Manure Form and Rate on Winter Wheat

Introduction

Spring application of liquid manure on winter wheat has proven to be a successful technique under European conditions. Both mid-March and mid-April liquid manure applications resulted in yields similar to those achieved with N fertilizer (Suess and Wurzinger, 1986). In Quebec, low doses of liquid manure (<20,000 l/ha) on spring cereals at tillering have also proven effective (Seydoux and Cote, 1991). Systems for post emergent use of liquid manure in cereals are being tested in Quebec and in Europe. One promising system uses tramlines for field traffic. Liquid manure is dribbled between cereal rows using flexible hoses mounted on a boom.

In Ontario, previous studies and farmer experience have shown that no-till seeding can be used successfully for establishing winter wheat after soybeans (Vyn et al., 1991). Winter wheat can also be aerially seeded into soybeans at leaf yellowing in early September in shorter season growing areas (<2700 corn heat units). However, few studies have compared its effectiveness with no-till establishment. From the standpoint of P loss, late spring application of liquid manure (by irrigation or tanker application) on high residue systems consisting of no-till or aerial seeded wheat following soybeans, could minimize negative environmental impacts associated with liquid manure applications at this time of the year. No-till wheat establishment would reduce surface runoff and increase field support for manure spreading equipment by increasing residue cover and minimizing soil disturbance.

In solid manure systems, several studies have found compost to be a better nutrient source and to result in better cereal yields than fresh manure. In these studies fresh and composted manure were incorporated into the soil prior to cereal planting (Ott, 1978; Sauerlandt, in Ott, 1978). Compost may be more suited to surface application in no-till systems than fresh manure. The former would have less N losses through volatilization and manure to soil contact would be greater than with fresh manure (Soltner, 1979).

This study was done to determine the potential of various manure sources and rates for no-till winter wheat production. Various N fertilizer rates were also evaluated in order to determine the N requirements of no-till winter wheat seeding systems following soybeans. The various establishment methods and fertilizer sources were also evaluated on fall red clover plowdown and fall weed growth as many farmers increasingly have difficulty establishing good clover stands following wheat. Successful establishment of red clover plowdown would help reduce any potential nutrient runoff problems after winter wheat harvest as well as reduce the N requirements for a corn crop which frequently follows wheat in Southern Ontario.

Table 30. Summary of Experimental Methods and Design

Main Plot Treatments : Winter wheat tillage systems	
1. Aerial seeded at leaf yellowing in soybeans	
2. No-till drilled (after soybean harvest)	
3. Conventional (one cultivation after soybean harvest)	
Subplots - Manure and fertilizer treatments	
1. Control 2. Fertilizer: 50 kg N/ha 3. Fertilizer: 100 kg N/ha 4. Liquid swine manure: 40,000 l/ha 5. Liquid swine manure: 80,000 l/ha 6. Mature swine and beef compost: 7.5 t/ha (1989) Immature dairy compost: 20 t/ha (1990) 7. Mature swine and beef compost: 15 t/ha (1989) Immature dairy compost: 40 t/ha (1990)	
Statistical Design	
Layout	Randomized complete block design with fertility treatments as split plot
Number of replications	4
Main plot size	6.6 m x 25 m
Sub plot size	2 m x 2 m
General Information	
Cooperator	Carl Ruby, Tavistock, Ontario
Soil type	Silt loam
Wheat seeding (no-till seeding performed with a conventional double disk opener drill, aerial seeding with hand cyclone)	Aerial seeded..........180 kg/ha No-till drill............120 kg/ha Conventional till......120 kg/ha
Wheat seeding dates	Aerial seeded...........Sept. 8/88 & Sept. 11/89 No-till drill..............Oct. 1/88 & Sept. 29/89 Conventional till....... Oct. 1/88 & Sept. 29/89
Wheat variety	Frederick
Wheat plant counts (3 x .25 m^2 quadrat)	April 25/89 & April 30/90
Red clover seeding (10 kg/ha common)	April 11/89 & April 23/90
Ground cover measurements (rope knot technique)	Oct. 6/88 & April 25/89 Oct. 24/89 & April 25/90
Spring manure application	April 28/89 and April 30/90 (manure weighed in buckets and broadcast or poured by hand)
Nitrogen applied (urea, hand broadcast)	April 28/89 & April 30/90
Leaf sampling (25 flag leaves/plot)	Aerial seeded..........June 14/89 & June 15/90 No-till ....June 19/89 & June 18/90 Conventional till.......June 19/89 & June 18/90
Wheat harvest (2.25 m^2 quadrat)	July 15/89 & July 31/90
Fall weed biomass (1 m^2 quadrat)	Oct. 10/89 & Oct. 2/90
Fall red clover biomass (1 m^2 quadrat)	Oct. 10-12/89 & Oct. 15-17/90

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Table 31. Nutrient Analysis of Compost and Liquid Swine Manure

Manure	Nutrient Concentration			Dry Matter
	%N	%P	%K	%
1989				
Beef Compost (mature)	1.12	0.46	0.48	39.6
Liquid Swine Manure	0.57	0.13	0.18	
1990				
Dairy Compost (immature)	0.69	0.40	0.35	30.2
Liquid Swine Manure	0.55	0.10	0.22	
	Total Nutrients Applied (kg/ha)			
	N	P	K	
1989				
Mature Compost: 7.5 t/ha	84	34.5	36	
Mature Compost: 15 t/ha	168	69	72	
Liquid Manure: 40,000 l/ha	228	52	64	
Liquid Manure: 80,000 l/ha	456	104	128	
1990				
Immature Compost: 20 t/ha	138	80	70	
Immature Compost: 40 t/ha	276	160	140	
Liquid Manure: 40,000 l/ha	220	40	88	
Liquid Manure: 80,000 l/ha	440	80	176	

Results and Discussion

Establishment and Ground Cover

In 1989, seedling establishment was approximately 1/3 greater in the aerial seeded wheat which was sown at 180 kg/ha compared to 120 kg/ha in the drilled treatments (Table 32). In 1990, no significant differences in wheat establishment were observed between treatments. Overall however, the winter wheat plant counts were higher than in the spring of 1989. The wheat was more advanced in late April in 1990 at the time plant counts were taken. This made it more difficult to perform plant counts as tillering had initiated and may have caused an overestimation of the plant density compared to 1989.

When no-till or aerial seeding techniques were used to establish the winter wheat, a high ground cover was maintained throughout the fall and spring period (Table 32). Aerial seeding produced a higher ground cover than no-till drilling. This may have been due to a combination of less soil disturbance during seeding and earlier seeding which resulted in better fall wheat growth. At the time of manure application in late April/early May, all of the winter wheat systems were providing high residue cover. Manure application on winter wheat at this time of year appears to be desirable from a soil erosion and runoff standpoint. An average of 57%, 80 % and 88% ground cover was present on the conventional, no-till and aerial seeded treatments respectively.

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Establishment and Ground Cover

In 1989, seedling establishment was approximately 1/3 greater in the aerial seeded wheat which was sown at 180 kg/ha compared to 120 kg/ha in the drilled treatments (Table 32). In 1990, no significant differences in wheat establishment were observed between treatments. Overall however, the winter wheat plant counts were higher than in the spring of 1989. The wheat was more advanced in late April in 1990 at the time plant counts were taken. This made it more difficult to perform plant counts as tillering had initiated and may have caused an overestimation of the plant density compared to 1989.

When no-till or aerial seeding techniques were used to establish the winter wheat, a high ground cover was maintained throughout the fall and spring period (Table 32). Aerial seeding produced a higher ground cover than no-till drilling. This may have been due to a combination of less soil disturbance during seeding and earlier seeding which resulted in better fall wheat growth. At the time of manure application in late April/early May, all of the winter wheat systems were providing high residue cover. Manure application on winter wheat at this time of year appears to be desirable from a soil erosion and runoff standpoint. An average of 57%, 80 % and 88% ground cover was present on the conventional, no-till and aerial seeded treatments respectively.

Table 32. Effect of Winter Wheat Establishment Method on Plant Establishment and Surface Residue

Treatments	Establishment Plants/m2		Ground Cover (%) 1988-89		Ground Cover (%) 1989-90	
	Spring 1989	Spring 1990	Oct. 6, 1988	April 25, 1989	Oct. 24, 1989	April 25, 1990
Aerial Seed	239 a	305	86.3 a	91.5 a	84.0 a	84.8 a
No-till	149 b	283	67.3 b	77.8 b	78.8 a	81.5 a
Conventional Till	156 b	312	27.5 c	52.2 c	20.3 b	60.8 b
C.V.	17.3 %	13.4 %	7.7 %	6.0 %	8.1 %	5.2 %

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Yield and Fertility Effects of Wheat Establishment Methods

Overall, establishment technique for winter wheat had no effect on yield when averaged over fertility treatments. This is consistent with other research evaluating winter wheat establishment following soybeans (Vyn et al., 1991). In 1989, no significant differences were observed in the nutrient status of wheat plants sampled at heading (Table 33 & 34). However, in 1990 the aerial seeded wheat had a significantly higher N content at the time of flag leaf analysis compared with the no-tilled wheat (Table 34). The conventionally tilled wheat had a flag leaf content intermediate to the aerial and no-till seeded wheat. In the conventionally tilled plots some nitrogen may have been mineralized when cultivation was performed prior to wheat seeding. The earlier planting date of the aerially seeded winter wheat may have reduced nitrogen leaching in the fall as it was better established at the onset of winter compared to the treatments which were seeded approximately 1 month later. The earlier establishment of winter wheat following soybeans may be important in improving nutrient cycling and reducing N requirements for the winter wheat. Visually, in early May 1989, the aerially seeded plot was a darker green than the conventionally tilled and no-till seeded plots. However, at the time of wheat heading, no significant differences in nitrogen content were observed (Table 34). This may have been related to the higher wheat density (1/3rd higher) in the aerially seeded plots (Table 32). The higher plant population in this treatment would create a greater demand on the available soil nitrogen as the wheat advanced in maturity and may have masked the differences that were visually observed earlier in the 1989 season.

Effect of Fertilizer Source on Flag Leaf N & P and Wheat Yield

In 1990, the semi-mature compost increased P supply to the wheat plants (Table 33). Most likely this was a result of the high amount of P applied with the compost and its' low N:P ratio (1.7: 1) compared to the liquid swine manure (5:1). With increasing rates of liquid manure or fertilizer the P content in the wheat plants appeared to be reduced. However, all of the P levels recorded in the wheat plants were well above the critical level of 0.1% established by the Ontario Ministry of Agriculture and Food (OMAF, 1990).

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Table 33. Effect of Fertility Treatments on Winter Wheat Flag Leaf P

Treatment	Average Wheat Flag Leaf P %		
Fertility Treatment (sub plot)	1989	1990	2 Year Avg.
Control	0.44 a	0.41 c	0.43
Fertilizer: 50 kg N/ha	0.31 d	0.41 c	0.36
Fertilizer: 100 kg N/ha	0.30 d	0.38 d	0.34
Liquid manure: 40,000 l/ha	0.39 b	0.43 b	0.41
Liquid manure: 80,000 l/ha	0.36 c	0.40 c	0.38
Compost (mature): 7.5 t/ha	0.44 a	-	-
Compost (mature) 15 t/ha	0.46 a	-	-
Compost (immature):20 t/ha	-	0.44 ab	-
Compost (immature): 40 t/ha	-	0.46 a	-
Establishment Method (main plot)			
Aerial Seed	0.38	0.42	0.40
No-till Drill	0.38	0.42	0.40
Conventional Till	0.41	0.42	0.42
C.V.	8.0 %	4.7 %	

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Large differences were observed in the wheat's nutrient content and yield over the two years of the study (Tables 32 & 34). Averaged over the two years, the low and high rates of liquid manure (containing approximately 220 kg N/ha and 440 kg N/ha respectively) provided almost identical leaf tissue analysis as the low (50 kg N/ha) and high (100 kg N/ha) rates of fertilizer respectively. This would indicate that only approximately 25% of the N applied was made available from the liquid manure. However, response differed in the two years. In 1989, fertilizer N produced the greatest leaf tissue N content while in 1990 it was the liquid manure. This may have been due to the weather conditions immediately after the fertilizer treatments were applied. In 1989, rain occurred within 24 hours of the fertilizer applications while in 1990 a period of dry weather followed. The dry weather in 1990 may have increased volatilization of N from the fertilized plots as the urea was applied to the soil surface. In both years the liquid manure infiltrated rapidly upon application. The rain following application of liquid manure in 1989 may have resulted in significant nutrient loss through the soil macropores and tile drains as reported by Dean and Foram (1990). In 1990, the high rate of liquid manure appeared to be excessive (wheat flag leaf nitrogen content of 4.3 %, Table 34). The grain lodged and the yield was reduced compared to the low and high rates of fertilizer and low rates of liquid manure. The two rates of compost had no significant effect on flag leaf N nutrient content or grain yield in 1989 (Table 35). The compost was mature (approximately 18-24 months old) and this may have been responsible for the lack of effect. The current trend in Europe is away from the production and utilization of an earthy, crumbly and friable organic material that

Table 33. Effect of Fertility Treatments on Winter Wheat Flag Leaf P

Treatment	Average Wheat Flag Leaf P %		
Fertility Treatment (sub plot)	1989	1990	2 Year Avg.
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Fertilizer: 50 kg N/ha	0.31 d	0.41 c	0.36
Fertilizer: 100 kg N/ha	0.30 d	0.38 d	0.34
Liquid manure: 40,000 l/ha	0.39 b	0.43 b	0.41
Liquid manure: 80,000 l/ha	0.36 c	0.40 c	0.38
Compost (mature): 7.5 t/ha	0.44 a	-	-
Compost (mature) 15 t/ha	0.46 a	-	-
Compost (immature):20 t/ha	-	0.44 ab	-
Compost (immature): 40 t/ha	-	0.46 a	-
Establishment Method (main plot)			
Aerial Seed	0.38	0.42	0.40
No-till Drill	0.38	0.42	0.40
Conventional Till	0.41	0.42	0.42
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has been composted for a long period of time. Rather systems in which the manure is placed in a windrow, bio-dynamic preparations are added, and the material is used immediately after the temperature drops are being adopted (Ott, 1990). In 1990, a compost fitting this description was obtained from a nearby biodynamic farm. Application rates were increased from the levels used in 1989. The 1990 compost produced higher nutrient concentrations in the wheat at heading and a significant yield increase at the high compost application rate. Yields from the compost plots probably could have been further improved if the compost had had a higher N content. Based on the N and K content of the compost relative to P, it appears that a significant amount of N and K may have been lost from the compost windrow. If the compost had been covered with a plastic sheet when it was in a windrow (as suggested by Lampkin, 1990) or if a more nutrient conserving composting system had been used (such as described by Mathur, 1990) a material with a higher N content might have been obtained.

It may have been possible to approach yields similar to those measured in plots fertilized with soluble forms of N, if a superior compost had been used in combination with the aerial or conventional seeding techniques. Both flag leaf N and wheat yield were higher in these treatments than in the no-till wheat which had low productivity when no fertilizer or compost was applied.

Table 34. Effect of Fertility Treatments and Establishment Methods on Winter Wheat Flag Leaf N

Treatments	Average Wheat Flag Leaf N %		
Fertility Treatment (sub plot)	**1989**	**1990**	**2 Year Average**
Control	2.69 d	2.95 e	2.82
Fertilizer: 50 kg N/ha	3.64 b	3.54 c	3.59
Fertilizer: 100 kg N/ha	4.15 a	3.86 b	4.01
Liquid manure: 40,000 l/ha	3.36 c	3.85 b	3.61
Liquid manure: 80,000 l/ha	3.71 b	4.33 a	4.02
Compost (mature): 7.5 t/ha	2.70 d	-	-
Compost (mature) 15 t/ha	2.68 d	-	-
Compost (immature): 20 t/ha	-	3.09 d	-
Compost (immature): 40 t/ha	-	3.18 d	-
Establishment Method (main plot)			
Aerial Seed	3.24	3.64 a	3.44
No-till Drill	3.20	3.46 b	3.33
Conventional Till	3.34	3.51 ab	3.43
C.V.	4.8 %	3.2 %	

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Table 35. Effect of Fertility Treatments and Establishment Methods on Winter Wheat Yield

Treatments	Average Grain Yield (t/ha) (12.5% moisture)		
Fertility Treatment (sub plot)	**1989**	**1990**	**2 Year Avg.**
Control	1.96 b	2.78 c	2.37
Fertilizer: 50 kg N/ha	3.86 a	4.48 a	4.17
Fertilizer: 100 kg N/ha	3.71 a	4.37 a	4.04
Liquid manure: 40,000 l/ha	3.92 a	4.33 a	4.13
Liquid manure: 80,000 l/ha	3.74 a	3.58 b	3.66
Compost (mature): 7.5 t/ha	2.13 b	-	-
Compost (mature) 15 t/ha	2.29 b	-	-
Compost (immature): 20 t/ha	-	2.94 c	-
Compost (immature): 40 t/ha	-	3.50 b	-
Establishment Method (main plot)			
Aerial seed	3.11	3.74	3.43
No-till drill	3.02	3.49	3.26
Conventional till	3.10	3.92	3.51
C.V.	12.4%	11.3%	

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Effect of Tillage and Fertility Treatments on Red Clover Plowdown and Weeds

In both years of the study, the winter wheat tillage system had no effect on red clover plowdown growth or weeds (Table 36). The fertility treatments had pronounced effects on both the biomass accumulation of red clover and weeds (Table 36). In both years of the study the treatments which possessed the highest flag leaf N content (100 kg fertilizer N/ha in 1989 and 80,000 l/ha of liquid manure in 1990 (Table 34)) produced the lowest quantity of red clover in the fall (Table 36). Linear correlation indicated R^2 values of .93 and .96 for flag leaf N concentration and clover biomass production for 1989 and 1990 respectively (Fig. 2 & 3). Excessive application of either fertilizer or manure appeared to have greatly suppressed red clover growth and enhanced fall weed growth. The effect of excessive fertility on the clover may have been caused by several factors: earlier and greater canopy closure by the winter wheat thereby reducing light interception by the establishing clovers; increased moisture stress for the establishing clovers because of increased foliar development in the winter wheat; and increased competition after harvest from cereal regrowth and weeds stimulated by residual soil N.

In 1990 the immature compost, which had significantly increased wheat yield (Table 35), caused no reduction in clover development or stimulation of fall weed growth compared to the control plot (Table 36). Reducing early season light

has been composted for a long period of time. Rather systems in which the manure is placed in a windrow, bio-dynamic preparations are added, and the material is used immediately after the temperature drops are being adopted (Ott, 1990). In 1990, a compost fitting this description was obtained from a nearby biodynamic farm. Application rates were increased from the levels used in 1989. The 1990 compost produced higher nutrient concentrations in the wheat at heading and a significant yield increase at the high compost application rate. Yields from the compost plots probably could have been further improved if the compost had had a higher N content. Based on the N and K content of the compost relative to P, it appears that a significant amount of N and K may have been lost from the compost windrow. If the compost had been covered with a plastic sheet when it was in a windrow (as suggested by Lampkin, 1990) or if a more nutrient conserving composting system had been used (such as described by Mathur, 1990) a material with a higher N content might have been obtained.

It may have been possible to approach yields similar to those measured in plots fertilized with soluble forms of N, if a superior compost had been used in combination with the aerial or conventional seeding techniques. Both flag leaf N and wheat yield were higher in these treatments than in the no-till wheat which had low productivity when no fertilizer or compost was applied.

Table 34. Effect of Fertility Treatments and Establishment Methods on Winter Wheat Flag Leaf N

Treatments	Average Wheat Flag Leaf N %		
Fertility Treatment (sub plot)	**1989**	**1990**	**2 Year Average**
Control	2.69 d	2.95 e	2.82
Fertilizer: 50 kg N/ha	3.84 b	3.54 c	3.69
Fertilizer: 100 kg N/ha	4.15 a	3.86 b	4.01
Liquid manure: 40,000 l/ha	3.36 c	3.85 b	3.61
Liquid manure: 80,000 l/ha	3.71 b	4.33 a	4.02
Compost (mature): 7.5 t/ha	2.70 d	-	-
Compost (mature) 15 t/ha	2.68 d	-	-
Compost (immature): 20 t/ha	-	3.09 d	-
Compost (immature): 40 t/ha	-	3.18 d	-
Establishment Method (main plot)			
Aerial Seed	3.24	3.64 a	3.44
No-till Drill	3.20	3.46 b	3.33
Conventional Till	3.34	3.51 ab	3.43
C.V.	4.8 %	3.2 %	

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Table 35. Effect of Fertility Treatments and Establishment Methods on Winter Wheat Yield

Treatments	Average Grain Yield (t/ha) (12.5% moisture)		
Fertility Treatment (sub plot)	**1989**	**1990**	**2 Year Avg.**
Control	1.96 b	2.78 c	2.37
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Liquid manure: 40,000 l/ha	3.92 a	4.33 a	4.13
Liquid manure: 80,000 l/ha	3.74 a	3.58 b	3.66
Compost (mature): 7.5 t/ha	2.13 b	-	-
Compost (mature) 15 t/ha	2.29 b	-	-
Compost (immature): 20 t/ha	-	2.94 c	-
Compost (immature): 40 t/ha	-	3.50 b	-
Establishment Method (main plot)			
Aerial seed	3.11	3.74	3.43
No-till drill	3.02	3.49	3.26
Conventional till	3.10	3.92	3.51
C.V.	12.4%	11.3%	

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In 1990 the immature compost, which had significantly increased wheat yield (Table 35), caused no reduction in clover development or stimulation of fall weed growth compared to the control plot (Table 36). Reducing early season light

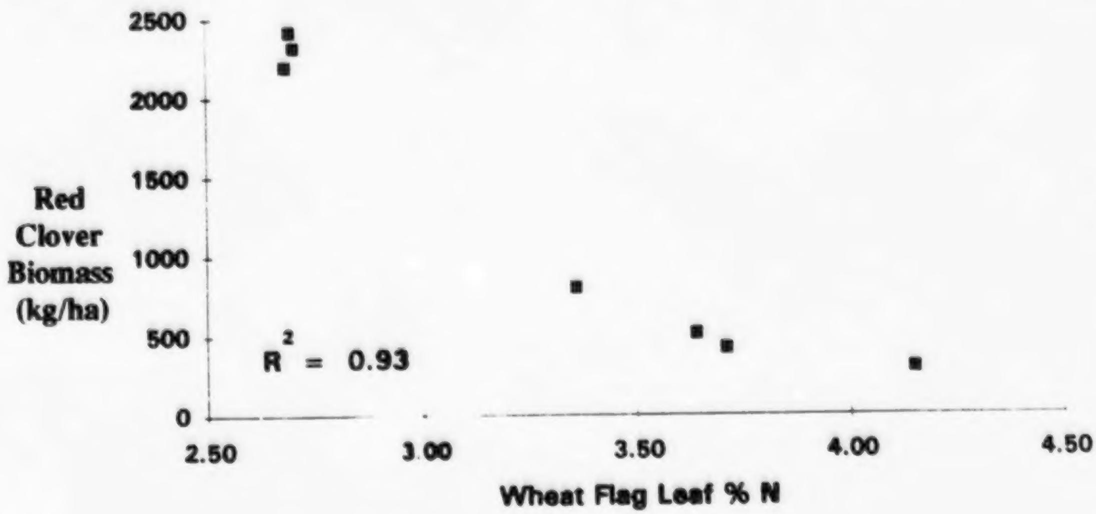
competition for establishing forages is important for early plant development. The slower nutrient release of compost is probably advantageous in this regard as it encourages good forage establishment but provides nutrients at a later stage to the winter wheat.

Table 36. Effect of Winter Wheat Fertility Treatments and Establishment Method on Fall Red Clover Plowdown and Weed Biomass

Treatment	1989		1990	
Fertility Treatment (sub plot)	**Red Clover**	**Weeds**	**Red Clover**	**Weeds**
	kg/ha		**kg/ha**	
Control	2416 a	18 b	2917 a	23 c
Fertilizer: 50 kg N/ha	**511 d**	**131 b**	**18[illegible] b**	**114 bc**
Fertilizer: 100 kg N/ha	**294 e**	**256 a**	**1071 c**	**198 ab**
Liquid manure: 40,000 l/ha	799 c	99 b	1150 c	226 a
Liquid manure: 80,000 l/ha	418 de	364 a	509 d	204 ab
Compost (mature) 7.5 t/ha	**2316 ab**	**28 b**	-	-
Compost (mature) 15 t/ha	**2196 b**	**26 b**	-	-
Compost (immature): 20 t/ha	-	-	2955 a	40 c
Compost (immature): 40 t/ha	-	-	2929 a	75 c
Wheat Establishment Method (main plot)				
Aerial seeded	1303	146	2032	127
No-till drilled	1315	152	1845	203
Conventional	1237	98	1929	90
C.V.	18.0%	108%	23.5%	87.4%

Note: Means within the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's multiple range test.

Figure 2. Correlation Between Flag Leaf N %and Red Clover Biomass in 1989



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Fertilizer: 100 kg N/ha	294 e	256 a	1071 c	193 ab
Liquid manure: 40,000 l/ha	799 c	99 b	1150 c	226 a
Liquid manure: 80,000 l/ha	418 de	364 a	509 d	204 ab
Compost (mature): 7.5 t/ha	2316 ab	28 b	-	-
Compost (mature): 15 t/ha	2196 b	26 b	-	-
Compost (immature): 20 t/ha	-	-	2955 a	40 c
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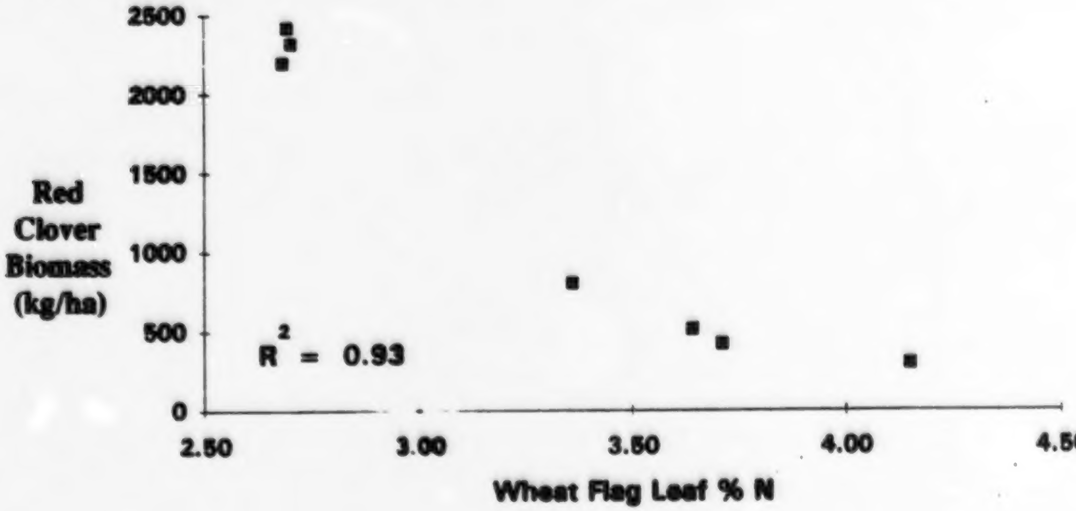
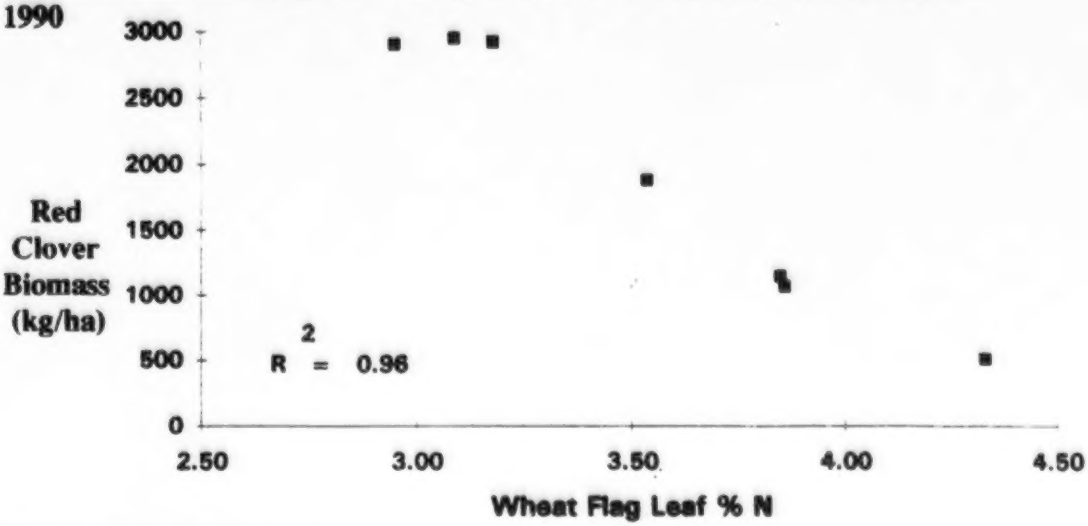


Figure 3. Correlation Between Flag Leaf N % and Red Clover Biomass in 1990



Concluding Discussion

The establishment of winter wheat following soybeans using no-till or aerial seeding techniques has proven to be a viable system which is being adopted by farmers in southern Ontario. Liquid manure application to winter wheat appears to be a viable alternative to commercial fertilizer as a nutrient source. Applications of 40,000 l/ha of liquid manure replaced the equivalent of approximately 50 kg fertilizer N/ha. This is similar to the estimated 15 kg N/ 10,000 L fertilizer substitution value for liquid swine manure provided by OMAF (1992) for surface application after seeding. Probably the N fertilizer substitution value of the liquid manure could have been improved if the liquid manure was dribbled into the winter wheat at tillering (10-15 cm tall wheat) with flexible hoses as currently is being practiced in Europe.

There are many advantages to applying liquid manure on no-till winter wheat at this time of the year including:

1. an early spring outlet for liquid manure;
2. application to a high residue cover thereby minimizing surface nutrient runoff;
3. rapid nutrient uptake occurs after application because of rapid development of the wheat crop at this time of year;
4. application of relatively low doses can be made which reduces pollution potential compared to the high dose applications that are made to corn at this time of the year.

The potential of compost as a fertilizer source for winter wheat also appears interesting as wheat yield was increased without affecting forage establishment. High rates of fertilizer or liquid manure suppressed forage establishment and increased fall weed growth. The combination of no till or aerial seeded wheat with manure appears to be a promising approach to the development of a low external input wheat production system which minimizes surface runoff risks.

Experiment 4

Effect of Solid Manure, Compost and Fertilizer on Established Forages

Introduction

Manure losses through runoff are likely to be small if manure is applied to established forages during the growing season. In Southern Ontario, both liquid manure and solid manure are frequently applied to alfalfa stands primarily after the first cut. An early summer outlet for manure is generally required on farms as storage at this time of the year tends to encourage fly problems. A number of studies have been performed on perennial forage crops evaluating the effects of liquid and solid manure applications.

Liquid manure applied to established perennial legume forages appears to affect stand equilibrium and productivity particularly when it is applied at high rates. The use of liquid manure frequently results in scorching of plants and suppression of legumes (Besson et al. 1987, Prins and Snijdres, 1987; Samson et al., 1990; Soltner, 1979; Kuntzel et al., 1987). Another problem of liquid manure applied to forages is an increase in perennial weed problems (Voisin, 1960; Hensler et al. 1970; Wasshausen, 1987). In Wisconsin, Hensler et al. (1970) evaluated the impact of applying high rates of liquid manure early in the spring after the first cut of a first year alfalfa grass stand. The greatest increase in the grass and weed components of the stand occurred in plots receiving a summer application of manure. This was particularly evident as rates increased to 134 t/ha (60 ton/acre). Spring applied manure had little effect on the legume composition of the mixture but total dry matter yields tended to decrease with increasing rates of manure application. The authors attributed the difference between spring and summer applications to the rain that fell following spring application. The lowest rates of application of 11-22 t/ha (5-10 ton/acre) appeared to have the least impact on reducing stand productivity and the legume component.

One way of reducing the scorching effect of the liquid manure has been to aerate the slurry to reduce the ammonia fraction. However, the results of this practice have been mixed to date. In a six year study, the application of aerobic and anaerobic liquid manure reduced the legume component of a stand (Besson et al., 1987). The authors concluded that the kind of manure, rate, time of application and physical distribution were more important than the type of slurry treatment. However in Germany, Abele ((1976) in Koepf, 1989) found aerated and biodynamically treated slurry resulted in better species equilibrium and increased productivity of the grass - clover mixtures.

High rates of liquid manure or solid manure appear to have more positive impacts on stand productivity when incorporated prior to seeding of the forage stand (Mathers et al., 1975; Sutton et al., 1979). The potential for nitrate pollution of the groundwater from manure application prior to alfalfa seeding appears to be minimal.

Over its lifetime, alfalfa removes NO_3-N from deep in the soil where annual crops are not effective in uptaking nutrients (Mathers et al., 1975). Alfalfa's high transpiration rate also depletes soil moisture levels which reduces the volume of water carrying nitrates to the groundwater.

For top dressing on forage stands, solid forms of manure appear to be more effective in maintaining good species equilibrium (Klapp (in Voisin, 1960) than liquid manure. They also appear to provide a more gradual release of nutrients than commercial fertilizer. When the availability of P from fertilizer and solid manure were compared, Goss and Stewart (1979) found alfalfa to be a luxury consumer of fertilizer P. Solid feedlot manure provided P more slowly for plant uptake and the P level remained adequate for a longer period of time than with the superphosphate. This was stated to be due to an increase in microbial activity as a result of the added energy source from the solid manure application. Thomas (1964) found that both applications of fertilizer or solid manure incorporated into the soil prior to alfalfa establishment increased the available P for each of four years of cropping. The effect of composting solid manure on yield and composition of legume based forages is not well established. Klapp (in Voisin, 1960) found that solid manure was more effective than composted manure in maintaining the legume fraction of the forage while Brinton (1988) found the opposite.

The present study was established to determine the effect of low rates of summer applied solid manure and compost on forage yield and composition. It was believed that compost would reduce manure clumping which smothers alfalfa plants and the risk of manure being present in the hay at the time of harvest. The manure was applied after the first cut, as most forage based livestock farmers require a late spring outlet for manure. On the farms in the area, early season manure application is generally done on corn fields and summer applications are done following cereal harvest. An erosion study was also performed at a nearby farm to determine the pollution risk of low rates of solid manure and compost on a moderately (6.5%) sloping alfalfa field.

Materials and Methods

A summary of the materials and methods used in the trial is provided in Table 35. Several weather related problems were experienced. In 1989, the spring was unusually wet which delayed the first cut. As a result, only one hay cut was taken after the fertilizer treatments were applied in the first year of the study. Winter kill occurred in low lying parts of the trial during the course of the study. As a result some plots were excluded from the trial. To deal with the missing data, a protected LSD was used in place of a protected Duncan's multiple range test (which was used in the analysis of the other experiments) in the data analysis.

Table 37. Summary of Experimental Methods and Design

Treatments	
Solid Beef Manure	10 t/ha
Mature Beef Compost	7.5 t/ha
Fertilizer	0-30-135 (triple super phosphate and muriate of potash)
Control	no fertilizer or manure
Statistical Design	
Layout	Randomized complete block design
Number of treatments	4
Number of Replications	4
Plot Size	4 m x 8 m
General Information	
Cooperator	Harry Wilhelm, Tavistock, Ont.
Soil type	Silt loam
Forage seeding	Alfalfa (10 kg) & timothy (2 kg/ha) established in 1988
Manure applications	Manure weighed in individual buckets and broadcast by hand
Fertility treatments applied	immediately after the first hay cut was harvested each year, July 4/89, June 28/90
Harvest method	Three x 1 m^2 quadrats/plot with forage sheared 6 cm above the soil, botanical separations were made of the harvested material to evaluate stand equilibrium
Harvest dates	1989: June 27 and Aug. 10 1990: June 14, July 24, and Aug. 20
Soil sampling	1989: July 4 and Aug. 28 1990: June 20 1991: May 2
Soil sampling method	0-15 cm depth, 10 cores/plot

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Table 38. Nutrient Analysis and Percent Dry Matter of Compost and Solid Manure Applied in 1989 and 1990

Manure	Nutrient Concentration			Dry Matter
	% N	% P	% K	%
1989	(on an as is basis)			
Compost	0.69	0.38	0.68	34.4
Solid Manure	0.64	0.13	0.73	36.4
1990				
Compost	0.70	0.375	0.807	32.9
Solid Manure	0.45	0.245	0.429	26.9
	Nutrients Applied (kg/ha)			
	N	P	K	
1989				
Compost: 7.5 t/ha	52	28.5	51	
Solid manure: 10 t/ha	64	13.0	73	
Fertilizer	0	30.0	135	
1990				
Compost: 7.5 t/ha	53	28.2	61	
Solid manure: 10 t/ha	45	24.5	43	
Fertilizer	0	30.0	135	

Results and Discussion

Stand Productivity

1989

In the first year of the study there was no significant effect of the fertility treatments on total forage yield or the content of the forage components (Table 39). The fertility treatments applied after the first cut had no significant effects on soil nutrient status at the time measurements were taken in late summer. Both the phosphorus and potassium levels at this site (Table 39) were low according to OMAF soil tests (OMAF, 1990).

1990

At the time of the first hay cut in 1990, the total forage yield was increased in both solid manure and compost treatments compared to the control treatment (Table 40). This appeared to be due to an increase in the grass yield of the stand. Alfalfa contributed only 1/3rd of the total biomass at this cut and was not significantly affected by any of the previous summer's fertility treatments.

At the time of the second hay cut in 1990, alfalfa was the dominant species of the forage harvested. No significant differences in total yield between treatments was

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At the time of the second hay cut in 1990, alfalfa was the dominant species of the forage harvested. No significant differences in total yield between treatments was

observed at the second cut. However, the fertilizer treatment significantly increased the alfalfa yield compared to the control treatment. On the third cut no treatment effects on yield were recorded. When the 1990 yields were evaluated over the entire year, all the fertility treatments increased the alfalfa yield and the total forage yield (Table 39). Only the solid manure treatment increased the total grass yield as well. This difference was also present when the grass yield data was analyzed over both years of the study. While all the treatments increased total forage yield compared to the control treatment, the solid manure treatment yielded the highest. This appeared to be due to increased grass and legume growth in 1990.

Table 39. Effect of Manure and Fertilizer Treatments on Forage Yield and Composition (yield average of 1 cut in 1989 and 3 cuts in 1990)

Treatment	1989			1990			1989 + 1990		
	Alfalfa	Grass	Total	Alfalfa	Grass	Total	Alfalfa	Grass	Total
	dry matter (kg/ha)			dry matter (kg/ha)			dry matter (kg/ha)		
Control	2270	589	2859	3948 c	4797 b	8745 c	6218 bc	5384 b	11602 c
Compost	2490	517	3007	4410 ab	5076 b	9484 b	6899 a	5592 b	12491 b
Solid Man.	2507	642	3149	4350 b	5736 a	10086 a	6859 ab	6379 a	13237 a
Fertilizer	2562	685	3247	4575 a	4713 b	9288 b	7136 a	5399 b	12534 b
C.V.	5.4%	15.0%	5.5%	1.6%	3.2%	1.8%	2.5%	4.4%	2.3%

Note: Means within the same column followed by the same letter are not significantly different according to the Fishers protected L.S.D. at the 0.05 level.

Table 40. Effect of Fertility Treatment on Forage Yield and Composition in 1990

Treatment	1st Cut			2nd Cut			3rd Cut		
	Alfalfa	Grass	Total	Alfalfa	Grass	Total	Alfalfa	Grass	Total
	dry matter (kg/ha)			dry matter (kg/ha)			dry matter (kg/ha)		
Control	1381	3041 c	4422 c	1209	307	1516	1357	1447	2805
Compost	1490	3576 ab	5066 ab	1433	462	1894	1487	1039	2525
Solid Man.	1551	3664 a	5215 a	1445	379	1824	1355	1693	3048
Fertilizer	1518	3151 bc	4669 bc	1488 *	417	1905	1569	1146	2715
C.V.	7.3%	5.7%	4.2%	8.1%	35.0%	12.1%	11.5%	22.9%	13.1%

Note: 1. Means within the same column followed by the same letter are not significantly different according to the Fishers protected L.S.D. at the 0.05 level.

2. * indicates significantly different than the control plot at 0.05 level according to L.S.D. test.

Soil Nutrient Dynamics

The soil nutrient levels declined throughout the course of the study. Prior to the re-application of the fertility treatments following the first cut in 1990, potassium declined the least in the fertilizer treatment and phosphorus declined the least in the solid manure treatment. At the time of soil sampling in the spring of 1991, the soil nutrient status had declined even further in all treatments. The compost and solid manure possessed higher soil P levels than the control plot and the fertilizer treatment had higher soil K levels than the control treatment.

Overall, the feasibility of using solid manure as a means of increasing the soil nutrient status of a low P or K soil appears marginal. Others have reported increases in soil P and K levels following high rates of manure application but these rates tend to be too high for optimal productivity of the stand and maintenance of the legume component.

Probably a more effective means of using manure in legume based forage production would be to: 1) use moderate rates of manure prior to forage establishment to ensure medium to high soil nutrient levels at the onset of production 2) make low dose applications of manure more frequently than once per year to maintain soil nutrient levels in high producing forage stands. This would reduce the need for high rates applications of solid manure or fertilizer as a means to increase soil nutrient levels during the lifetime of the stand. It probably is unrealistic to expect surface applications of solid manure to be a viable means of increasing soil nutrient levels from low levels, rather the objective should be to prevent decline.

Table 41. Effect of Manure Treatments and Fertilizer on Soil Nutrient Levels 1989-1991.

Treatment	Phosphorus (ppm)				Potassium (ppm)			
	July 4/89	Aug. 28/89	June 29/90	May 2/91	July 4/89	Aug. 28/89	June 29/90	May 2/91
Control	11.3	5.3	4.0	2.7 c	60	58	38 b	22
Compost	-	7.0	5.5	3.5 ab	-	65	41 ab	28
Solid Manure	-	5.7	5.7 *	4.0 a	-	71 *	44 ab	28
Fertilizer	-	2.3	5.0	3.0 bc	-	69	47 a	32 *
C.V.		64.9%	14.5%	9.8%		7.6%	8.1%	12.0%

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Rainfall Simulation

The rainfall simulation results appearing in the appendix (Table 42) indicates that there is little potential for P loading into water courses from either applications of solid manure or compost to alfalfa fields after the harvest of the first hay crop. Two of the main factors contributing to the low P runoff loss at this time of year include:

1. alfalfa crop transpiration depletes soil moisture which encourages water infiltration and reduces runoff potential,

observed at the second cut. However, the fertilizer treatment significantly increased the alfalfa yield compared to the control treatment. On the third cut no treatment effects on yield were recorded. When the 1990 yields were evaluated over the entire year, all the fertility treatments increased the alfalfa yield and the total forage yield (Table 39). Only the solid manure treatment increased the total grass yield as well. This difference was also present when the grass yield data was analyzed over both years of the study. While all the treatments increased total forage yield compared to the control treatment, the solid manure treatment yielded the highest. This appeared to be due to increased grass and legume growth in 1990.

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Compost	1480	2576 ab	[illegible] ab	1433	462	1894	1487	1039	2526
Solid Man.	1551	3664 a	5215 a	1445	379	1824	1355	1693	3048
Fertilizer	[illegible]	3181 bc	[illegible] bc	1488 *	417	1905	1569	1146	2715
C.V.	7.3%	5.7%	4.2%	8.1%	35.0%	12.1%	11.5%	22.9%	13.1%

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	July 4/89	Aug. 28/89	June 29/90	May 2/91	July 4/89	Aug. 28/89	June 29/90	May 2/91
Control	11.3	5.3	4.0	2.7 c	80	58	38 b	22
Compost	-	7.0	5.5	3.5 ab	-	65	41 ab	28
Solid Manure	-	5.7	5.7 *	4.0 a	-	71 *	44 ab	28
Fertilizer	-	2.3	5.0	3.0 bc	-	69	47 a	32 *
C.V.		64.9%	14.5%	9.8%		7.6%	8.1%	12.0%

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1. alfalfa crop transpiration depletes soil moisture which encourages water infiltration and reduces runoff potential,

2. ground cover approaches 100% because of the rapid regrowth of the forage stand after cutting.

Concluding Discussion

Both low rates of solid manure and compost moderately stimulated effect on productivity of a forage stand on a low fertility site. Top dressing low rates of manure or moderate rates of fertilizer had only a slight impact on reducing the decline of soil nutrient reserves which were low at the beginning of the experiment. The goal of top dressing manure on established perennial forages should be to help reduce the decline in nutrient levels rather than to increase them.

It appeared that a mid-summer application of either fresh or composted manure applied to the surface of established forages on a moderately (6.5 %) sloping field is unlikely to result in greater soil and P loss compared to a forage stand to which no manure was applied (Table 42). Overall the pollution risk due to surface runoff appears minimal where low rates of solid or composted manure are applied to established forages in mid-summer. While this does not necessarily represent an efficient use of manure it is an outlet with minimal surface run-off potential. Negative agronomic responses appear minimal and in some instances (such as under the low soil fertility levels experienced in the present study) are positive. Probably, moderate applications of solid manure (25-35 t/ha) prior to forage establishment would have been an effective means of increasing the low nutrient status of the soil. Many dairy farms are in a surplus nitrogen position because of protein and grain imports and use of legume based forage stands. Using solid manure prior to establishment of hay fields at moderate rates and at low rates during the summer after hay cutting appear to be techniques that can minimize surface nutrient loss and groundwater loading of nitrates.

A useful set of guidelines for top dressing manure on alfalfa has been developed by the University of Wisconsin (Kelling, 1985). It states:

1. Alfalfa fields that contain the most grass, usually the oldest stands, will derive the most benefit from nitrogen in manure.
2. Apply no more than 21,000 l/ha of liquid manure or no more than 22 tonne/ha of solid manure. Applying more may cause salt burn, and damage or suffocate plants. Use supplemental fertilizer if additional nutrients are required.
3. Apply the manure immediately after removing a cutting so manure contacts the soil instead of the foliage. This reduces the risk of salt burn and avoids palatability problems.
4. Adjust the spreader to break up large chunks or pieces of manure that can smother regrowth.
5. Limit soil compaction and avoid damaging crowns by spreading only when soils are firm.

Experiment 4 Appendix:

Runoff, Sediment and Phosphorus Losses Resulting from Manure Applications to Perennial Forages (performed by Ecological Services for Planning, Guelph, Ont.)

Site Description

Manure applications were made to a second year stand of perennial alfalfa forage in 1989. Fresh solid manure was applied at a rate of 20 t/ha, and beef manure compost was applied at a rate of 15 t/ha. A no-manure control was also used. Rainfall simulation was performed 5 days after manure application to evaluate its effect on the size of runoff, sediment and phosphorus losses. The site was located on the farm of L. Bender, South Easthope Township, Perth Co. The site had a uniform slope of 6.5 %. The soils on the site were a loam surface texture with a pH of 5.1 and organic matter content of 2.5 %. Rainfall simulation was carried out on July 13 and 14, 1989. Alfalfa regrowth was approximately 10 cm high at the time of the rainfall event.

Statistical Analysis

Statistical analyses were conducted on data using multiple comparisons (Tukey's HSD). Significance was determined at $P < 0.10$.

Results and Discussion

No statistically significant differences were detected for any of the parameters measured including runoff volume, soil loss and P loss (Table 42). In some ways these results may be expected because the soil cover provided by the perennial forage was 97 % on average for the field. It may have been expected that surface applications of manure would result in greater P losses, from both greater concentrations in the sediment and dissolved fraction (Mueller, 1984). The volume of runoff collected from any one rainfall event varied from 0.10 to 1.7 L. On average, the amount of runoff was low, 0.60 L for manure and no-manure applications. Similarly, soil losses were small during the 10 minute rainstorm, averaging less than 1.0 g soil/m^2 (0.76 g/m^2), or an average sediment concentration of 2.0 g sediment/L runoff. Analysis of the runoff and sediment volumes revealed a mean concentration of P of 1.1 g P/kg soil, meaning that 0.85 mg P/m^2 was lost during simulated rainstorm. Soluble P levels averaged 0.45 P/L runoff. The P concentrations in the runoff were greater than for other studies conducted in the SWEEP program and runoff volumes generally lower. Soluble P loss amounted to 0.17 mg P/m^2.

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It appears that a midsummer application of either fresh solid manure (20 t/ha) or composted manure (15 t/ha) applied to the surface of established forages on a moderately (6.5%) sloping field is unlikely to result in greater soil and P losses relative to where no manure is applied.

Table 42. Runoff, Soil and P losses From Rainfall Simulation on Perennial Forages

Treatment	Runoff Volume (L/m^2)	Soil Loss (g/m^2)	Total P Loss ($mg P/m^2$)	Ortho - P Loss (mg/m^2)
None	0.58	0.62	0.67	0.13
Fresh Solid Manure	0.28	0.51	0.53	0.18
Compost	0.93	1.14	1.35	0.21
Overall mean	0.60	0.76	0.85	0.17

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V. General Discussion

A number of factors have contributed to the present situation in which manure is a major source of nutrient pollution. For the nutrient pollution problem to be seriously addressed de-intensification strategies in both livestock rearing and crop production methods will be required. In Southern Ontario the most serious manure management problems occur on swine farms. Not only are livestock densities high but fertilizer use, surprisingly, is high as well. Ontario's annual farm management analysis survey of agricultural producers indicates that Ontario hog farmers spend as much or slightly more per acre on fertilizer than do Ontario cash crop farmers (OMAF, 1989). Part of this can be explained by different cropping patterns (i.e. that hog farmers grow slightly more corn and less soybeans than cash crop farmers) but the hog farmer is also importing significant quantities of nutrients through the purchase of soybean based protein supplements. It is suggested that there are several reasons for the high fertilizer use on hog farms:

1. Farmers are not adequately crediting their manure and are over fertilizing as a result;
2. Manure is being used inefficiently and large losses are being incurred;
3. Compaction problems associated with liquid manure tankers is reducing nutrient use efficiency and as a result high fertilization is required.

Strategies to efficiently use manure, reduce fertilizer use, modify tillage systems and increase ground cover on these farms are required if the situation is to be improved. The current crop rotation on many of the farms in the study area consists of 3-4 years of row crops (one year of which may be in soybeans) followed by 1 year of spring cereals. Currently manure is applied in the spring prior to corn planting at high rates as soon as the soil is reasonably dry; on the spring cereal stubble; and after corn harvest at high rates to clean out the manure storage facilities prior to the onset of winter. Fall plowing is used in an attempt to alleviate the compaction problems and to maintain corn productivity as reduced tillage may reduce yield when corn follows corn. Although there have been major changes in the past several years, this problematic series of practices is still observed on the majority of farms in the study area.

In the present study, 3 of the 4 alternative manure and crop management strategies are for hog farms. Two of the systems evaluated are already being implemented on swine farms in the study area:

1. liquid manure application on no-till seeded winter wheat following soybeans;
2. liquid manure application to winter wheat stubble followed by seeding of an oilseed radish catch crop and planting of corn in the subsequent year using a conservation tillage system (Aerway, no-till or chisel plow).

The third technique of using winter rye as a no-till cover crop for soybeans is being used mainly by cash crop farmers who are generally using Glyphosate to kill the rye. The application of liquid swine manure prior to rye seeding may be an interesting alternative manure management system particularly for swine farms that are experiencing soil tilth problems.

Introducing soybeans and winter cereals into crop rotations on hog farms would bring diversity to the present cropping patterns and may improve nutrient cycling and soil quality relative to the present land use. In a planned manure management system, relatively low rates of manure (40,000 l/ha) could be used as a maximum application during any one season while still obtaining optimal yields. However, there is need for a strategic plan to efficiently use the manure in the crop rotation. For example in the study where winter wheat followed soybeans, 40,000 l/ha of liquid swine manure applied in late April provided sufficient N for a full wheat crop. In corn, an application of 40,000 l/ha in the late summer followed by an oilseed radish catch crop and a subsequent 40,000 l/ha of liquid manure the following spring would likely provide a N self sufficient corn crop. The following systems are included not as optimal systems for the study area but as a guideline for the integration of crop rotations, low dose manure applications, cover cropping and reduced tillage.

In the shorter growing season areas (2700 CHU) or less a possible rotation including the cropping concepts discussed in this project could include:

Main Crop and Cover Crop	Manure Application	Tillage System
Yr. 1- Corn (ryegrass interseeding)	Prior to corn planting or as a sidedress	Fall chisel
Yr. 2- Spring Cereal / Winter rye	Post emergent on spring cereal and prior to rye seeding	Stubble disked prior to rye seeding
Yr. 3- Soybeans / Winter Cereal	None	No-till soybeans (into rye) and winter cereal
Yr. 4- Winter Cereal / Oilseed radish	On winter cereal at the onset of tillering and prior to or on oilradish catch crop	Fall chisel plow oilseed radish

In the longer growing season areas > 2700 CHU the rotation could include:

Main Crop and Cover Crop	Manure Application	Tillage System
Yr. 1- Corn (Annual ryegrass interseeding)	Prior to corn planting or as a sidedress	Ridge-till
Yr. 2- Soybeans / Winter cereal	None	Ridge-till soybeans, No-till winter cereal
Yr. 3- Winter Cereal / Oilseed radish	On winter cereal at onset of tillering and prior to or on oilradish catch crop	No-till oilseed radish into cereal stubble

This later example could be set out in a strip-intercropping system to improve crop productivity (through increased light interception) and further reduce erosion (the field length would be dramatically reduced) as is being practiced by several cash crop farmers in Southern Ontario (Samson, 1992).

VI. Recommendations for Future Research

Further Evaluation of Manure Management in Conservation Farming for Pollution Control

1. Corn

a) Compare split applications of liquid swine manure (application late summer before oilseed radish seeding and side-dressed in the spring) versus late summer application with oilseed radish catch crop or spring application;

b) Evaluate nitrogen leaching losses and nutrient cycling effects of manure application prior to oilseed radish versus post emergent applications on established oilseed radish in mid-September;

c) Evaluate ground cover, ortho-P losses and total P losses associated with various oilseed radish establishment methods managed in several minimum tillage systems.

2. Soybeans

a) Evaluate the impact of liquid manure on winter rye managed as a no-till cover crop for soybean on P losses and nutrient effects on soybeans;

b) Evaluate ortho-P and total-P losses from a rye cover crop and other cover crops killed at various stages of maturity when managed as a no-till mulch.

3. Winter Wheat

a) Evaluate various methods for applying low doses of liquid manure on winter wheat;

b) Examine the impact of manure application on no-till wheat versus conventionally tilled wheat on nutrient movement through soil macropores;

c) Examine the agronomic response of different composting methods techniques on undersown spring and winter cereals.

4. Perennial forages

a) Examine the impact of higher rates of solid manure and compost on maintaining soil nutrient levels and stand composition over time;

b) Compare the effects of manure, manure + rock phosphate, compost, compost + rock phosphate and triple super phosphate as P sources and on luxury P consumption in perennial forages.

5. Manure Systems Research

a) Examine the impact of changing from present day liquid swine manure systems (consisting of an audit of the total nutrient load coming out of barn, field application loading levels and residual N at the end of the season) to those that reduce pollution potential both in the barn and the field.

b) Compare manure applications to perennial forages versus corn on nitrate leaching and P losses from the farm as whole. The potential for corn to use a manured alfalfa crop as a N source and the decline of microbial biomass as a P source could also be included.

c) Determine whether fertilizer P is being over applied and contributing to P pollution as a result of the lack of soil and manure testing, poor understanding of soil test results &/or inappropriate soil test recommendations (particularly from certain U.S. labs used by local fertilizer dealers).

d) Examine the various P loading sources from farms to identify which are the most serious (e.g. manure storage, application, erosion, surface runoff &/or milk house wastes etc.)

VII. References

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